REPRESENTATIVE JOB "BUILDING" FOR VIDEO ANALYSIS COMPLETED USING THE UTAH ERGONOMIC ANALYZER

by

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SUPERVISORY COMMITTEE APPROVAL

of a thesis submitted by

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FINAL READING APPROVAL

To the Graduate Council of the University of Utah:

I have read the thesis of Tyson E. Skinner in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the supervisory committee and is ready for submission to The Graduate School.

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ABSTRACT

Many ergonomists strive to find links between physical risk factors and injuries in the workplace. To accomplish this, workers are observed in the workplace as they complete their daily jobs and an analysis is performed in real time. An alternative to this type of analysis is to record the workers completing their jobs using video cameras and then later perform a more in depth analysis. Although video analysis provides many benefits, it can be very time consuming and quite monotonous. Some jobs take many hours, even multiple days to analyze using video analysis techniques. Therefore, in order to be more efficient and save time, the following method was tested.

The method included analyzing one representative cycle of the elements that were completed many times throughout each job. Once the representative element was analyzed, it was used for each instance that the specific element occurred resulting in a "built job." This greatly reduced the time of analysis since the element was only analyzed one time rather than the multiple times that it occurred in the representative job cycle. This led to a substantial time savings while still obtaining a reliable analysis and representation of the job of interest.

Two analytical methods were used to compare the data between the fully analyzed job and the built job. The first was a basic comparison of averages, standard deviations and percent differences. The second was an intraclass correlation coefficient.

Overall, the results showed that this is a reliable method to analyze jobs and saves a substantial amount of time. There was a maximum percent difference between the built jobs and the fully analyzed jobs of 24%, where a majority of the built jobs resulted in a 15% difference or less. All of the built jobs resulted in an excellent reliability according to the ICC analysis. For the 31 jobs analyzed the new method reduced the analysis time by an average of 59%. Therefore, it was confirmed that this is a suitable method for analyzing jobs with the intention of reducing injury in the workplace and saves a great deal of time.

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CHAPTER 1

INTRODUCTION

Background

Many ergonomists have strived to find a better, less exhausting, and less stressful method for analyzing repetitive jobs. In order to do this, various studies have been completed to determine which tasks, postures and methods are more prone to injury. Many of these studies include video analysis to capture the tasks completed by workers because it has many benefits over completing an onsite, real time analysis.

Upper Extremity Cumulative Trauma Disorders (UECTD)

It has been found that there are various factors that contribute to Upper Extremity Cumulative Trauma Disorders (UECTD) which are also known as Upper Extremity Musculoskeletal Disorders (UEMSD). These disorders are defined as "disorders of the nerves, muscles, tendons, and bones that are caused, precipitated, or aggravated by repeated exertions or movements of the body." Some examples of the more common injuries include, but are not limited to, tendonitis and Carpal Tunnel Syndrome (CTS) and Thoracic Outlet Syndrome (TOS) (Bloswick & Joseph, 2007, p. 517).

Of the many causes, the most prominent are awkward postures, undesirable or high force, high rate of repetition and long durations of work without adequate rest

(Thornbory, 2004). Therefore, in order to reduce the number of UECTD's these causes should be reduced.

It was estimated by the Health & Safety Executive (HSE), a United Kingdom nondepartmental public body, that "there are more than one million people (in Great Britain) that suffer from Musculoskeletal Disorders (MSD), caused or made worse by a workplace activity" (Thornbory, 2004, p. 18). Resulting injuries can impede or even disable workers thus costing companies thousands of dollars in both direct (medical) and indirect (lost productivity) costs. Although CTS is not the only disorder that has disabling effects, it was estimated that those with CTS were absent from work an average of 17 weeks. It was also calculated that the mean cost for upper extremity claims in the United States and Canada during the 1990s ranged from $5,000 to $8,000 in indirect costs alone (Baldwin & Butler, 2006).

Video Analysis

Video recording can be a very useful tool to use while evaluating jobs. Videos allow the analyst the ability to fast forward, rewind and pause the task being completed. This is very beneficial since there are many actions occurring and not all of them can be effectively evaluated in real time.

Video analysis has been used in many studies attempting to prevent injuries in the workplace. For example, the Project on Research and Intervention in Monotonous Work (PRIM) used video analysis to determine the effects of repetitive tasks in the Danish work environment. The use of video analysis enabled them to obtain "estimates of repetitiveness, body postures, force and velocity parameters that constituted 43 single exposure items" that could contribute to UECTD's (Fallentin et al., 2001, p. 23).

Although video analysis gives a great advantage over real time analysis, there are still some drawbacks associated with it. There are some instances when the camera angle can incorrectly portray or distort postures. This can result in a skewed analysis. Also, the view of the camera can become blocked which does not leave a direct view of the worker. Both of these can be resolved by using multiple cameras recording several perspectives at the same time. The most difficult drawback to resolve is the tediousness involved with analyzing the videos. As an attempt to ease the monotony of video analysis, various programs have been developed. These programs enable users to easily step through the video while classifying the actions being completed.

Looking into the future, there are great advancements being made to aide in the automatic extraction and analyses of multiple periodic motions that occur in video sequences. A study was completed that stated they were able to "successfully extract the object periods" which are used to "extract the corresponding objects and, thus, achieve motion segmentation" (Briassouli & Ahuja, 2007, p. 1260). If these types of motions can be recognized and extracted then these types of programs would aide in video analysis.

Utah Ergonomic Analyzer (UTEA)

The Utah Ergonomic Analyzer (UTEA) is a video analysis program that was developed by the University of Utah. Work on the UTEA continues and the program is periodically improved base on analysts' feedback. The UTEA enables users to incrementally step through videos frame by frame while classifying the postures, rating the speeds and efforts and rating values on a perceived effort scale known as the Rating of Perceived Exertion (RPE or Borg) (Borg, 1970). Another key feature of this program is that it allows the user to preview the video, step forward and backward several frames and then easily return to the classification menu. This enables the user to better understand the actions being performed and results in a better analysis. A screen shot of the current data collection interface for the UTEA program can be seen in Figure 1. A list of the UTEA's outputs along with their brief descriptions can be seen in Appendix A.

Various other studies are currently being completed, or have already been completed, to test various attributes of the UTEA program. For example, a thesis titled Efficacy of the Utah Ergo Analyzer at Various Frame Rates was completed at the University of Utah in 2006. This research tested, in part, that "observers could accurately assess attributes of a job" and that "users could learn to use the software tool quickly" (Rodriguez, 2006, p. 3).

Ergonomic Activity Compiler (EAC)

The Ergonomic Activity Compiler (EAC) is another program that was developed by the University of Utah. The EAC has been referenced as the "Distiller" by the research team. The EAC uses the UTEA outputs to compute various summary characteristics of the job being analyzed. These summary characteristics can then be used to evaluate the job and determine the tasks that are presumably most stressful and therefore most likely to result in a UECTD. A screen shot of the EAC program interface can be seen in Figure 2. A list of the EAC's outputs along with their brief descriptions can be seen in Appendix B.

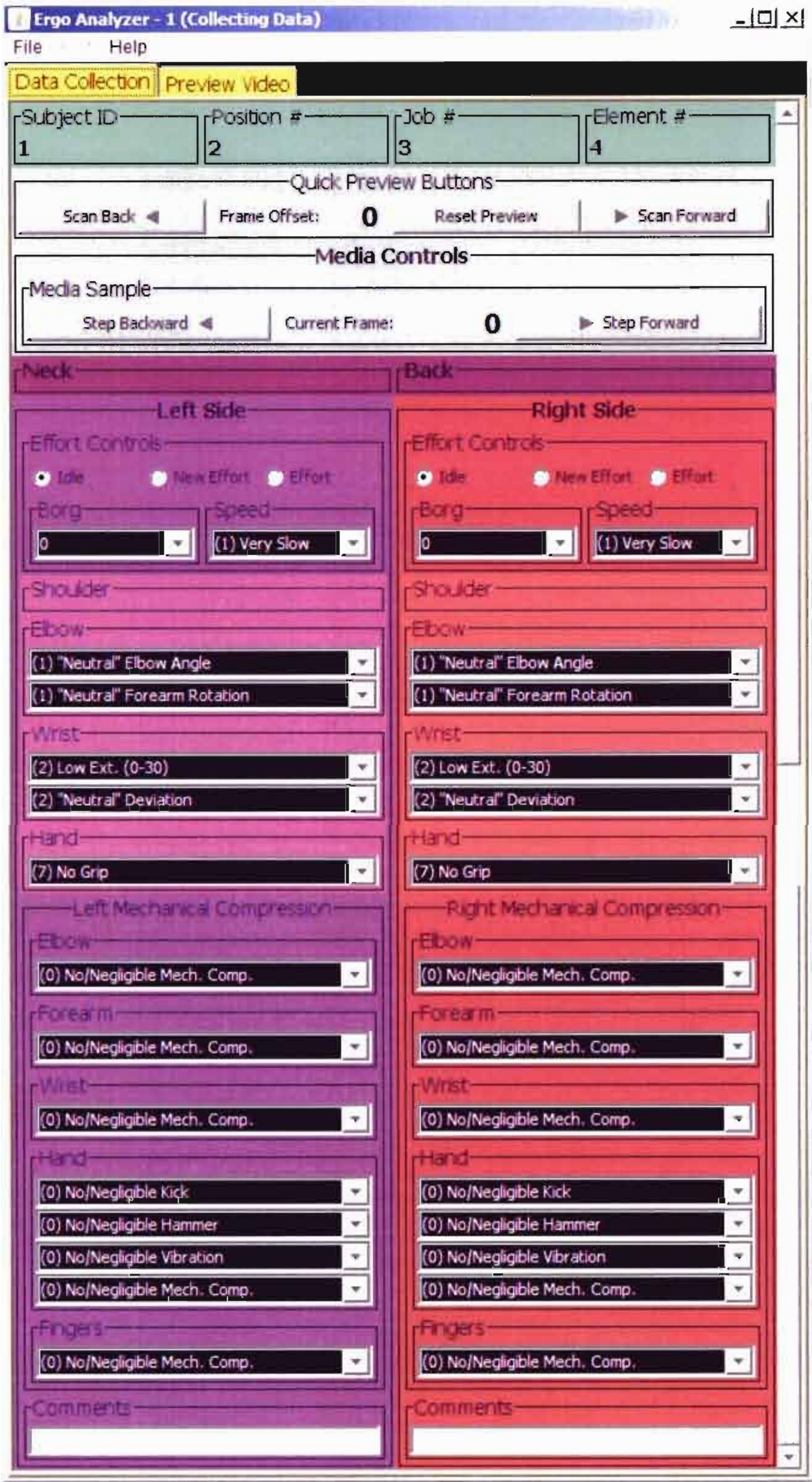

Figure 1: UTEA Interface

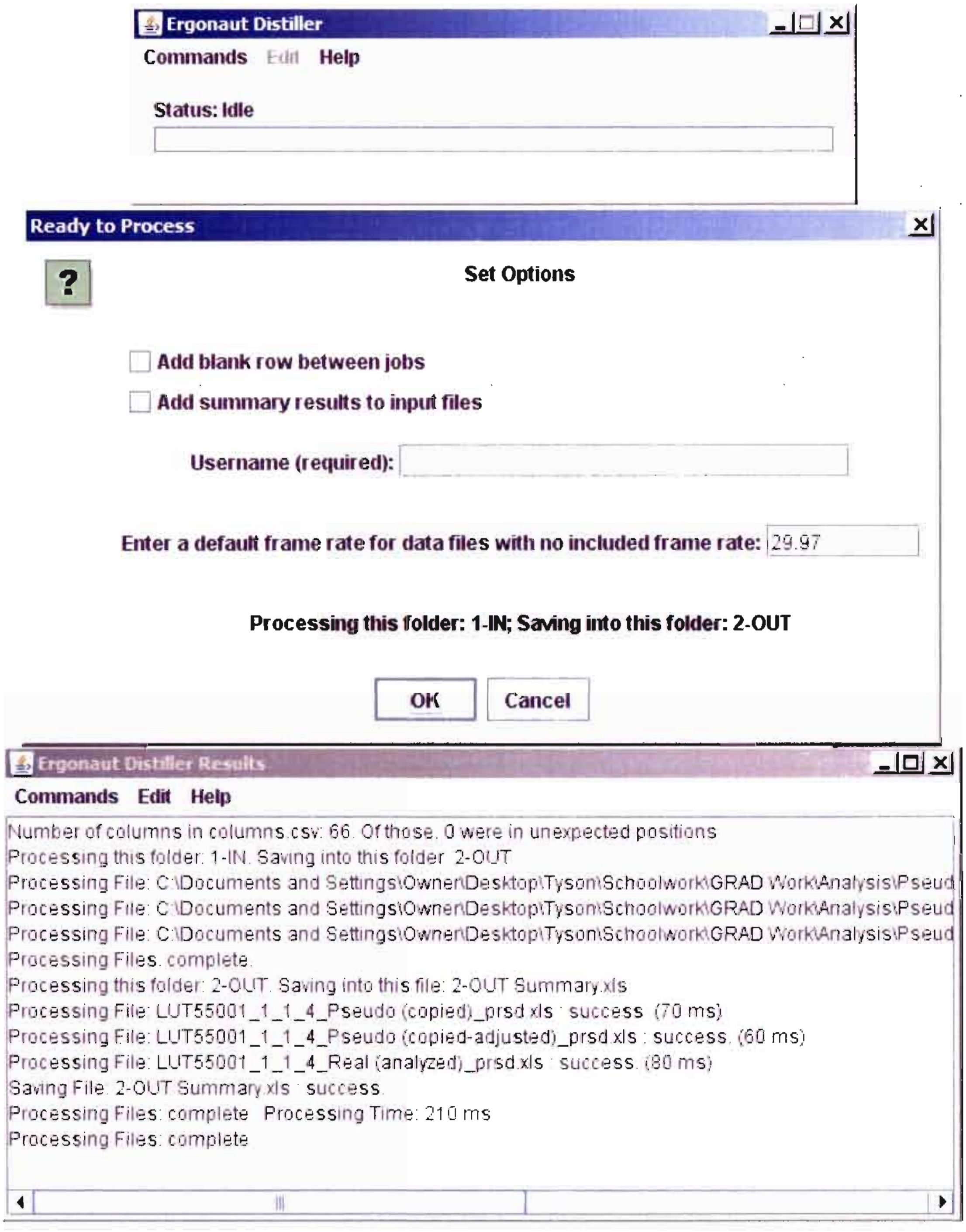

Figure 2: EAC Interface

Purpose of the Research

A large ongoing prospective study began in 2003 with the purpose of developing methods to evaluate the risk of injury in repetitive workplace environments. The study is funded by the National Institute for Occupational Safety and Health (NIOSH) and is known as Upper Extremity Musculoskeletal Disorders: Identifying Risk, NIOSH Grant Number 5 U01 0H07917-03.

The study involves hundreds of consenting subjects from many different work environments. The work environments include, but are not limited to, a medical device production facility, a meat packing facility and a garment manufacturing facility. The subjects were first given a medical exam and then video recorded completing their daily tasks. These tasks were then analyzed using a video analysis program, the UTEA, in order to determine the risk of the jobs being completed and the associated injuries.

Video analysis, although useful, can be very monotonous. The videos for this study were characterized a minimum of three times per second (every 333 milliseconds). Several of the jobs studied take more than an hour to complete in real time. This means that the videos for these particular jobs would need to be characterized more than 10,800 times. This would take days to complete and would be mentally exhausting. The tedious nature of such a long analysis would also increase the likelihood of error

Fortunately, most of the videos involved various elements that were repeated multiple times. The repetitiveness of analyzing jobs was the inspiration for this thesis. This thesis studies the feasibility of characterizing one of the representative elements completed during the video and then repeating it the number of times that it occurs throughout the video. This results in a "built job."

As the research progressed, it was discovered that the number of efforts were significantly higher than expected for certain jobs. This is the result of the way that "new efforts" and continuing "efforts" were classified in the elements. This occurred when one hand continued an effort while the other hand performed several efforts. For example, if a subject held a bucket with the left hand and placed several items into the bucket with the right hand, a representative element might include placing one item into the bucket. If this element was repeated for the number of times an item was placed into the bucket, then the left hand's number of efforts would be exaggerated. It would appear that the subject is newly grasping the bucket each time a new item is loaded, when in reality it was grasped once and held continuously until the bucket was fully loaded by the right hand. Overestimations of this type became known to the research team as "bucket" examples. As a result, a method was developed to adjust the built job so that it better correlated to the fully analyzed job.

To clarify, while classifying the jobs, a "new effort" was used when the subject touched an object, changed direction or changed the level of exertion while an "effort" is a continuation of the existing effort taking place. See Figure 3.

Hypotheses

The following hypotheses were tested for this research:

Hypothesis # 1

The need to find an easier and more efficient method for analyzing videos is very essential. A very viable solution would be to analyze small elements of the overall job

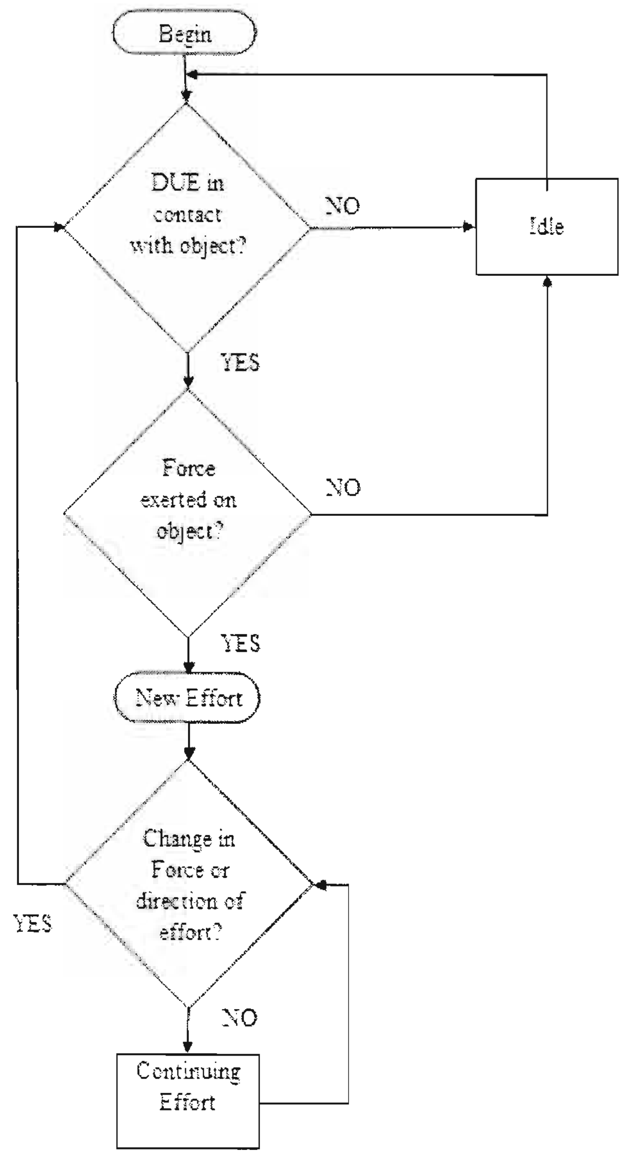

Figure 3: Effort Classification

and then combine them to create the complete job. Therefore, the first hypothesis is that built jobs will yield results that are representative of the fully analyzed job.

Hypothesis # 2

While comparing the built jobs and fully analyzed jobs it was found that the method previously employed did not properly account for the differences between "efforts" and "new efforts" for some tasks due to the so called "bucket" effect. This leads to the second hypothesis that the adjusted built jobs will yield results that better represent the fully analyzed job than the initial unadjusted built jobs.

CHAPTER 2

METHODOLOGY

Study Design

Each subject involved in the study held numerous positions and completed multiple jobs which were each composed of various elements. Therefore, the study was structured as shown in Figure 4. This enabled the researchers to keep track of the various positions held, jobs involved within each position and elements involved within each job.

The subject ID is a randomly assigned number used to identify each subject yet keep their personal information confidential. The position and jobs were assigned prior to filming the videos based on the subjects' descriptions of tasks completed. The elements were not defined until the videos were filmed. Once the jobs were captured the elements were carefully chosen by reviewing the video. This process involved watching the video multiple times and identifying repeated tasks and elements.

Job Building

Since the elements are a crucial part of this research they will be described in more depth. In order to obtain a general idea of tasks completed during the jobs, the videos were first observed at a playback speed of 2-3x the normal speed.

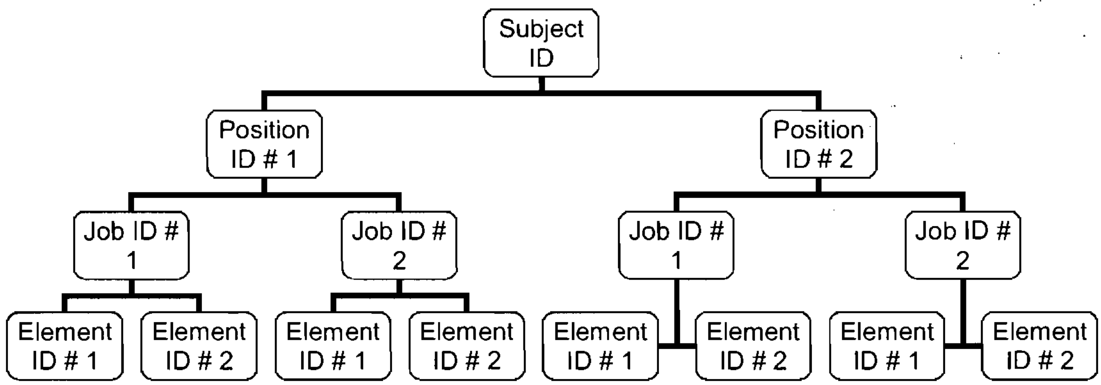

Figure 4: Study Structure

The video was then observed again in real time to document each element involved for that video. The specific start and stop frames as well as the number of occurrences for each element were also documented. The start and stop frames were later used to analyze the videos using the UTEA program. The number of occurrences for each element was later used to compose the built jobs. These breakdowns served as the "recipes" for creating the built jobs.

Throughout the videos there were many instances where the worker completed nonstressful Distal Upper Extremity (DUE) activities such as walking, sitting or resting without any significant DUE movement or activity. These instances were treated differently to save time and effort. Since the activities that did not involve an effort had little, if any, effect on the end results of interest, the nonstressful DUE activities were categorized into one of two generic elements. The first generic element was a bent arm nonstressful activity. This generic element characterized the posture of an individual with their arms to their sides, elbows at a 90 degree angle and neutral postures of the hands and wrists. The second generic element was a straight arm nonstressful activity. This generic element characterized the posture of an individual with their arms at their sides, their arms straight and neutral postures of the hands and wrists. These generic elements were used when there were no efforts being completed. This saved a lot of time. Otherwise, additional elements would have been needed to analyze each job. These nonstressful DUE activities would not have changed any of the existing ergonomic risk assessment outcomes. Therefore, simplifying their collection greatly enhanced the analysis efficiency. Also, the lengths of the elements throughout the jobs were not always the same. Since the nonstressful DUE activities were only single observations they were used to equalize the lengths of the built jobs to the lengths of the fully analyzed jobs. While reviewing the videos the type of nonstressful DUE activity was documented later to be used to build the jobs.

Once analyzed, all of the appropriate elements needed to be compiled for each job. The jobs were created by duplicating the elements the specified number of times as documented in the "recipe" obtained from the breakdown of the video. As explained above, the videos were then equalized by filling the remaining observations with the nonstressful DUE activity elements. This played an important part in the analysis by ensuring that the fundamental cycle length was accurately estimated.

For this research, jobs were not built in the same order as they occurred in the fully analyzed jobs. This would have required extra documentation while watching the videos and was deemed unnecessary for this study. This was decided because the end item calculations were not driven by the order that the elements occurred rather by the amount of times that the elements occurred. No existing ergonomic risk assessments were affected by this decision.

Improved Method – Adjusted Built Jobs

As the research progressed it was found that there was a fairly large difference between the unadjusted built jobs and fully analyzed jobs with regards to average posture for an effort, efforts per minute and hand activity level. This was due to the method that was used to classify the elements efforts.

The elements were chosen based upon the main activity being performed. Therefore, if the main activity was being performed by the right hand then the classification of the left hand, with regards to efforts versus new efforts, was not correctly captured as explained in the "bucket" example. Each time an element was analyzed both the left and right hands would begin with a "new effort." This would be correct for the first time a part was placed into the bucket. However, every subsequent time a part was placed into a bucket a "new effort" would be counted for the left hand as well as the right hand. The right hand completing the main action would be correctly captured, but the left hand should really be counted simply as an "effort." As stated before the "bucket" example highly over estimated the new efforts for the left hand.

In order to account for this, each element was classified into one of the various different categories. These categories can be seen in Table 1. An "N" meant that the element and each successive copy of that element were correct as initially analyzed. An "L-F" or an "R-F" meant that the respective hands first instance of the element had a "new effort", but every successive element after that began with an "effort." The "L-N" or the "R-N" meant that none of the instances for that element began with a "new effort"; all of the element instances began with an "effort." These were cases where the "new effort" was captured by an element previously completed and therefore did not need to be

Table 1: Adjusted Element Classification

N	No Change to the Element
L-F	Left Hand First Instance New Effort Change to Element
L-N	Left Hand No New Effort Change to Element
R-F	Right Hand First Instance New Effort Change to Element
R-N	Right Hand No New Effort Change to Element

counted again in the current element.

If this method were applied to the "bucket" example there would be no notations for the right hand. The main activity was performed with the right hand; therefore, each element would begin with a "new effort" for the right hand. Using the improved method, the left hand would be classified by an "L-F". This would keep the "new effort" for the first copy of the element, but every successive copy would start with an "effort" for the left hand.

Data Compiling

Once the fully analyzed jobs were classified, the unadjusted and adjusted built jobs were "built" using the analysis from the "full" jobs. They were then run though the EAC program. This program output valuable information such as the average RPE for the job, the average speed during an effort, the average speed for the job, the average hand wrist posture, efforts per minute and the percentages of work cycle spent in different postures. A complete list of the categories that this research focused on can be seen in Table 2.

Table 2: EAC Categories of Interest

Forearm Rotation Percentage for an Effort
Elbow Angle Percentage for an Effort
Flexion/Extension Percentage for an Effort
Grip Percentage for an Effort
Wrist Deviation Percentage for an Effort
Average RPE for an Effort
Average RPE for a Job
Maximum RPE
Average Effort for a Job
Efforts Per Minute
Hand Activity Level
Average Hand Wrist Posture
Maximum Hand Wrist Posture
Average Posture for an Effort
Average Speed for an Effort
Average Speed for a Job
Maximum Speed

Description of Sample

In order to test the similarity between the built jobs and the fully analyzed jobs, 31 randomly selected tasks were used for analysis. The tasks were short portions of the entire jobs that included multiple elements that could be broken down. These complete tasks are referred to as the fully analyzed job, or "full" jobs. The fully analyzed jobs were first analyzed using the UTEA program. The video analysis was completed on all of the frames that made up the fully analyzed job which included multiple instances of the various elements.

In order to obtain the elements, the most representative cycle of that element was then copied from the complete analysis and saved separately as the individual element. Elements were obtained by this method in the interest of time and with the goal of reducing the analysts' variation in classification of the video. This eliminated the variation due to intrarater reliability, or the variation of analysis by the same person from one time to another. This was employed so that this intrarater reliability error did not confound the results of the built jobs. Intrarater and interrater reliability is currently being studied at this time. Preliminary results indicate relatively good interrater reliability among experienced analysts.

Data Analysis

In order to determine the similarities between the built jobs and the fully analyzed jobs, the data were analyzed in two different ways. Some basic statistical values such as average, standard deviation and percent difference were first calculated. Then an Intraclass Correlation Coefficient (ICC) was calculated to compare the unadjusted built jobs to the fully analyzed jobs and the adjusted built jobs to the fully analyzed jobs. The ICC is a measure of the similarity between the two analysis methods.

Averages, Standard Deviations and Percent Differences

The averages and standard deviations were calculated for the unadjusted built jobs, the adjusted built jobs and the fully analyzed jobs for the many different categories listed in Table 2. The percent difference, as shown in (Equation 1), was then calculated in two different ways. First, the percent difference was calculated using the averages of all of the values for each method, thus giving the percent difference of the means. Second, the absolute percent difference was calculated for each individual sample pair and then the average of these percent differences was computed, thus giving the average of the percent differences. This was completed for the unadjusted built jobs versus the fully analyzed jobs and the adjusted built jobs versus the fully analyzed jobs. A summary of these calculations can be seen in Appendix C.

$$Percent\_Difference = \left(\frac{full - built}{full} \right) * 100\% \qquad \text{(Equation 1)}$$

where

full is the value from the category of interest from the fully analyzed job; and

built is the value from the category of interest from the built job.

Percent Difference Interpretation

For ease of interpretation the following rating scale was developed:

- "poor" for a percent difference > 25.0
- "marginally acceptable" for a percent difference of 20.0-24.9
- "acceptable" for a percent difference of 10.0-19.9
- "good" for percent difference of 5.0-9.9
- "excellent" for percent difference of 0.0-4.9

ICC Calculations

Next the ICCs were calculated for all of the different categories using SPSS release 16.0.1 for Windows. In order to reduce the number of categories for analysis, similar output types were grouped together. For example, all three of the elbow angle percentages (<70, neutral and >135) were grouped together. The ICCs were calculated comparing the unadjusted built jobs to the fully analyzed jobs and the adjusted built jobs to the fully analyzed jobs. The ICC calculations were completed using a model of 3 (two-way mixed) and a form of 31 (an average of the 31 samples). Therefore, an ICC(3,31) analysis was completed. This type of model was chosen for the ICC analysis because each job was evaluated by each method (unadjusted built jobs, adjusted built jobs and fully analyzed jobs) and these are the only methods of interest. This form was chosen because the reliability was calculated by taking the average of the 31 samples for each method. Each calculation was completed using a Confidence Interval (CI) of 95%. A complete summary of the ICC calculations can be seen in Appendix D.

ICC Interpretation

When categorizing data, the reliability "can be somewhat arbitrary and highly subjective" and "there are several variables that can cause similar data sets to exhibit different reliability results even when using the same reliability coefficient" (Stevens, Vos, Stephens, & Moore, 2004). Consequently, when reviewing the results presented keep in mind that they may not be absolute.

Understanding the ICC results can sometimes be a little difficult. Therefore, for ease of understanding, various interpretations have been developed. ICC's were described by Fleiss (1986) as:

- "poor" reliability for an ICC < 0.40
- "fair" to "good" reliability for an ICC of 0.40-0.75
- "excellent" reliability for an ICC > 0.75

A more refined description was given by Landis and Koch (1977) as:

- "poor" reliability for an ICC < 0.00

- "slight" reliability for an ICC of 0.00-0.20
- "fair" reliability for an ICC of 0.21-0.40
- "moderate" reliability for an ICC of 0.41-0.60
- "substantial" reliability for an ICC of 0.61-0.80
- "almost perfect" reliability for an ICC of 0.81-1.00

CHAPTER 3

RESULTS

General Results

Overall, the data show that the built jobs result in good representations of the fully analyzed jobs. The only categories that are not as representative for the unadjusted built jobs are the average posture for an effort and efforts per minute, both of which were improved using the adjusted built job method. Hand Activity Level (HAL) is also affected by the adjusted built job method. However, many of the observed values are outside of the ranges covered by the American Conference of Governmental Industrial Hygienists (ACGIH) HAL evaluation; therefore the HAL category was disregarded.

There were sixteen different EAC outputs that were analyzed. All of these various outputs were categorized into one of the following groups for ease of discussion: posture percentage during an effort, exertion level (intensity), hand wrist posture, speed and categories affected by adjusted built job method.

The results of these groups will be presented next. A summary of the results for the left hand can be seen in Table 3 and a summary for the right hand results can be seen in Table 4. Keep in mind that an ICC value of 0.00 means that there does not appear to be a meaningful relationship between the methods and a value of 1.00 represents perfect reliability.

Table 3: Left Hand Results Summary

			Unadjusted			Adjusted		
			% Diff of Ave.	Ave. % Diff	ICC	% Diff of Ave.	Ave. % Diff	ICC
Left	Overall Forearm Rotation Percentage for an Effort		0.0	11.5	0.987	0.0	11.5	0.987
		Pronated Percentage for an Effort	2.7	17.1		2.7	17.1	
		Neutral Percentage for an Effort	1.2	7.7		1.2	7.7	
		Supinated Percentage for an Effort	5.2	9.7		5.2	9.7	
	Overall Elbow Angle Percentage for an Effort		0.0	11.2	0.996	0.0	11.2	0.996
		<70 Percentage for an Effort	0.9	11.0		0.9	11.0	
		Neutral Percentage for an Effort	0.5	8.6		0.5	8.6	
		>135 Percentage for an Effort	1.9	14.1		1.9	14.1	
	Overall Flexion/Extension Percentage for an Effort		0.0	12.4	0.950	0.0	12.4	0.950
		High Flexion Percentage for an Effort	3.0	0.1		3.0	0.1	
		Moderate Flexion Percentage for an Effort	41.7	10.2		41.7	10.2	
		Low Flexion Percentage for an Effort	3.8	25.7		3.8	25.7	
		Low Extension Percentage for an Effort	0.4	17.2		0.4	17.2	
		Moderate Extension Percentage for an Effort	8.5	19.9		8.5	19.9	
		High Extension Percentage for an Effort	0.0	0.0		0.0	0.0	
	Overall Grip Percentage for an Effort		0.0	9.9	0.967	0.0	9.9	0.967
		Power Hook Percentage for an Effort	1.1	2.9		1.1	2.9	
		Oblique Percentage for an Effort	0.0	0.0		0.0	0.0	
		Palmer Percentage for an Effort	10.0	7.2		10.0	7.2	
		Palmer Pinch Percentage for an Effort	10.8	17.6		10.8	17.6	
		2 or 3 Point Pinch Percentage for an Effort	4.6	19.0		4.6	19.0	
		Key Pinch Percentage for an Effort	40.4	5.7		40.4	5.7	
		Contact Percentage for an Effort	5.7	16.9		5.7	16.9	
	Wrist Deviation Percentage for an Effort		0.0	16.0	0.977	0.0	16.0	0.977
		High Ulnar Percentage for an Effort	4.4	8.3		4.4	8.3	
		Moderate Ulnar Percentage for an Effort	0.1	16.9		0.1	16.9	
		Neutral Percentage for an Effort	2.2	15.8		2.2	15.8	
		Radial Percentage for an Effort	20.8	23.0		20.8	23.0	
	Average RPE for an Effort		1.6	5.3	0.993	1.1	4.5	0.993
	Average RPE for a Job		5.1	11.7	0.977	5.1	11.8	0.977
	Maximum RPE		2.6	1.6	0.984	2.6	1.6	0.984
	Average Effort for a Job		1.1	3.7	0.988	1.1	3.7	0.988
	Average Hand Wrist Posture		1.8	10.3	0.894	1.8	10.3	0.894
	Maximum Hand Wrist Posture		12.2	7.7	0.832	12.2	7.7	0.832
	Average Speed for an Effort		1.2	2.0	0.992	1.2	2.0	0.992
	Average Speed for a Job		6.3	7.1	0.977	6.2	7.1	0.977
	Maximum Speed		0.0	0.0	1.000	0.0	0.0	1.000
	Average Posture for an Effort		6.1	13.0	0.652	0.1	7.1	0.945
	Efforts Per Minute		54.8	146.4	0.621	10.9	22.0	0.966

Table 4: Right Hand Results Summary

		Unadjusted			Adjusted		
		% Diff of Ave.	Ave. % Diff	ICC	% Diff of Ave.	Ave. % Diff	ICC
	Overall Forearm Rotation Percentage for an Effort	0.0	20.0	0.975	0.0	20.0	0.975
	Pronated Percentage for an Effort	3.2	36.3		3.2	36.3	
	Neutral Percentage for an Effort	3.5	19.5		3.5	19.5	
	Supinated Percentage for an Effort	62.0	4.3		62.0	4.3	
	Overall Elbow Angle Percentage for an Effort	0.0	8.7	0.994	0.0	8.7	0.994
	<70 Percentage for an Effort	14.4	4.8		14.4	4.8	
	Neutral Percentage for an Effort	2.1	6.9		2.1	6.9	
	>135 Percentage for an Effort	3.9	14.3		3.9	14.3	
	Overall Flexion/Extension Percentage for an Effort	0.0	10.6	0.992	0.0	10.6	0.992
	High Flexion Percentage for an Effort	78.5	3.4		78.5	3.4	
	Moderate Flexion Percentage for an Effort	33.3	12.8		33.3	12.8	
	Low Flexion Percentage for an Effort	7.7	10.4		7.7	10.4	
	Low Extension Percentage for an Effort	0.2	4.9		0.2	4.9	
	Moderate Extension Percentage for an Effort	44.7	20.7		44.7	20.7	
	High Extension Percentage for an Effort	15.7	10.4		15.7	10.4	
	Overall Grip Percentage for an Effort	0.0	13.3	0.950	0.0	13.3	0.950
	Power Hook Percentage for an Effort	0.0	7.4		0.0	7.4	
Right	Oblique Percentage for an Effort	79.5	7.2		79.5	7.2	
	Palmer Percentage for an Effort	13.7	8.0		13.7	8.0	
	Palmer Pinch Percentage for an Effort	2.9	14.0		2.9	14.0	
	2 or 3 Point Pinch Percentage for an Effort	2.6	16.9		2.6	16.9	
	Key Pinch Percentage for an Effort	93.1	6.8		93.1	6.8	
	Contact Percentage for an Effort	12.0	32.6		12.0	32.6	
	Wrist Deviation Percentage for an Effort	0.0	11.9	0.980	0.0	11.9	0.980
	High Ulnar Percentage for an Effort	25.2	9.9		25.2	9.9	
	Moderate Ulnar Percentage for an Effort	21.7	11.1		21.7	11.1	
	Neutral Percentage for an Effort	0.9	18.9		0.9	18.9	
	Radial Percentage for an Effort	13.4	7.7		13.4	7.7	
	Average RPE for an Effort	0.6	3.4	0.996	0.4	3.7	0.995
	Average RPE for a Job	5.9	10.4	0.967	5.9	10.3	0.967
	Maximum RPE	4.7	2.7	0.953	4.7	2.7	0.953
	Average Effort for a Job	0.1	4.7	0.985	0.1	4.7	0.985
	Average Hand Wrist Posture	1.3	5.3	0.952	1.3	5.3	0.952
	Maximum Hand Wrist Posture	7.3	4.3	0.871	7.3	4.3	0.871
	Average Speed for an Effort	0.3	0.3	0.999	0.3	0.3	0.999
	Average Speed for a Job	4.6	6.5	0.940	4.6	6.4	0.940
	Maximum Speed	0.0	0.0	1.000	0.0	0.0	1.000
	Average Posture for an Effort	0.6	4.7	0.952	0.6	4.7	0.953
	Efforts Per Minute	20.7	31.2	0.930	15.8	23.7	0.947

Posture Percentage During an Effort Results

The five categories analyzed for this group did not vary from the unadjusted built jobs to the adjusted built jobs. This is because they are solely dependent upon the posture, therefore, are not changed by the adjusted method. The categories included in this section are the forearm rotation percentage, elbow angle percentage, flexion/extension percentage, grip percentage and wrist deviation percentage. Bar graphs for the average percent differences and ICC's of this group can be seen in Figure 5 and Figure 6, respectively.

As shown, the overall forearm rotation percentage results in a 20.0 % difference of the right hand which had the greatest percent difference for this group. This is a little higher than desired, but is still marginally acceptable and yields an ICC of 0.975. This results in an excellent, or almost perfect, reliability. The greatest percent difference for the left hand is 16.0% in the wrist deviation percentage category. The wrist deviation for the left hand results in an ICC of 0.977 also showing an excellent reliability.

Ultimately, all posture percentage categories yield comparable results with regards to the average percent differences. They all result in an excellent, or almost perfect, reliability since all categories yielded an ICC of 0.950 or better.

Exertion Level (Intensity) Results

This group consists of the four categories that include exertion levles. The categories in this group are the average RPE for an effort, the average RPE for a job, the maximum RPE and the average effort for a job. The bar graph of the average percent differences for this category can be seen in Figure 7 and the ICC bar graph can be

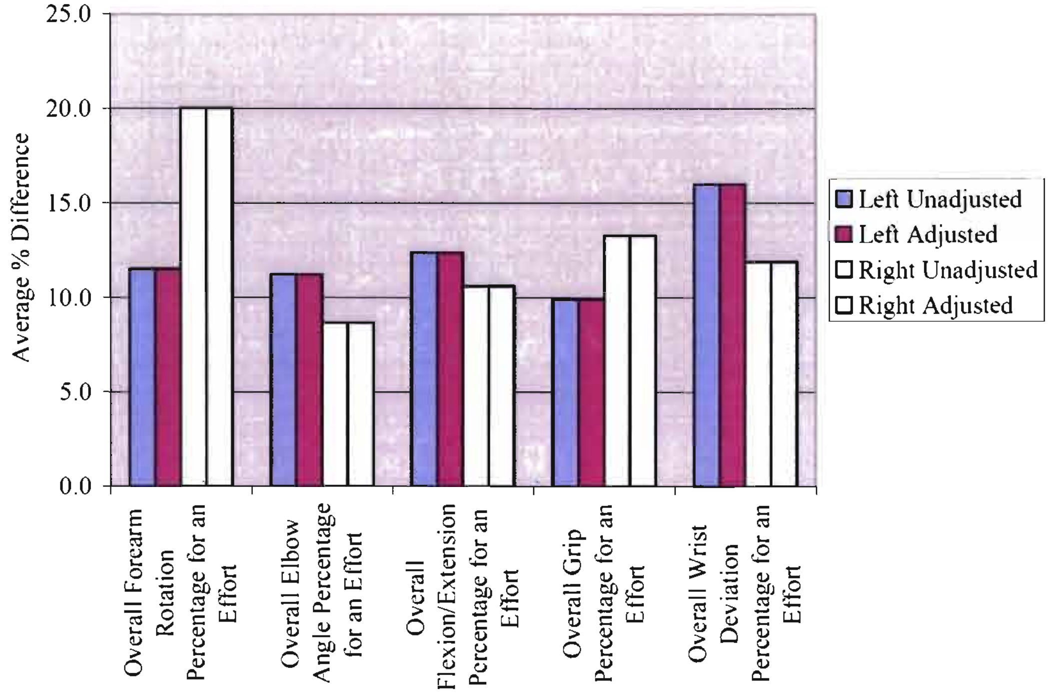

Figure 5: Posture Percentage During an Effort Percent Difference Results

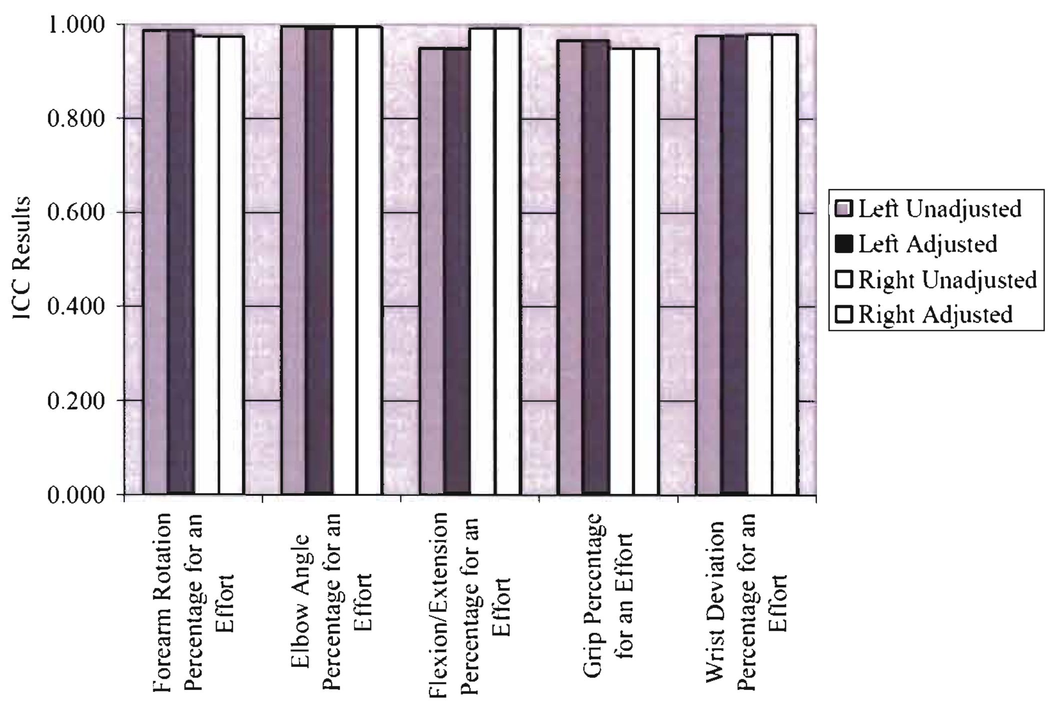

Figure 6: Posture Percentage During an Effort ICC Results

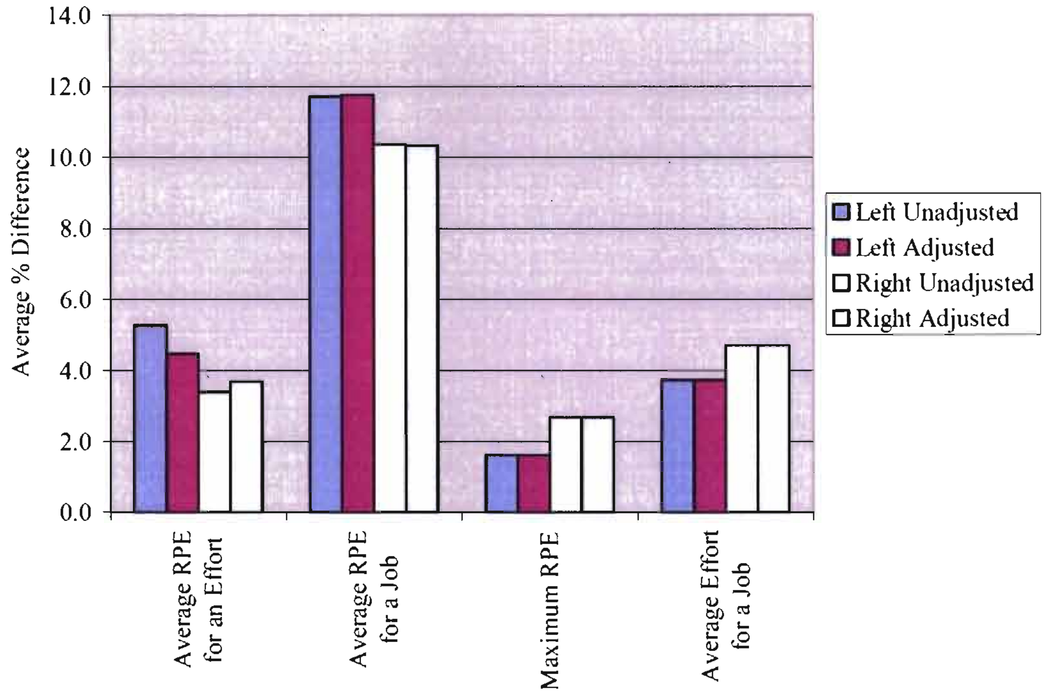

Figure 7: Exertion Level Percent Difference Results

seen in Figure 8.

The exertion level results yield better results than the posture percentages. The greatest percent difference for this category is 11.8% in the left hand average RPE for a job. The ICC for the left hand average RPE for a job is 0.977 which shows excellent, or almost perfect, reliability. The right hand's greatest percent difference is also in the average RPE for a job, which yields 10.4% with an ICC of 0.967.

The overall RPE group yields acceptable results for the average percent difference of 11.8% or better. This group results in an ICC of 0.953 or better showing that these categories also have excellent reliability.

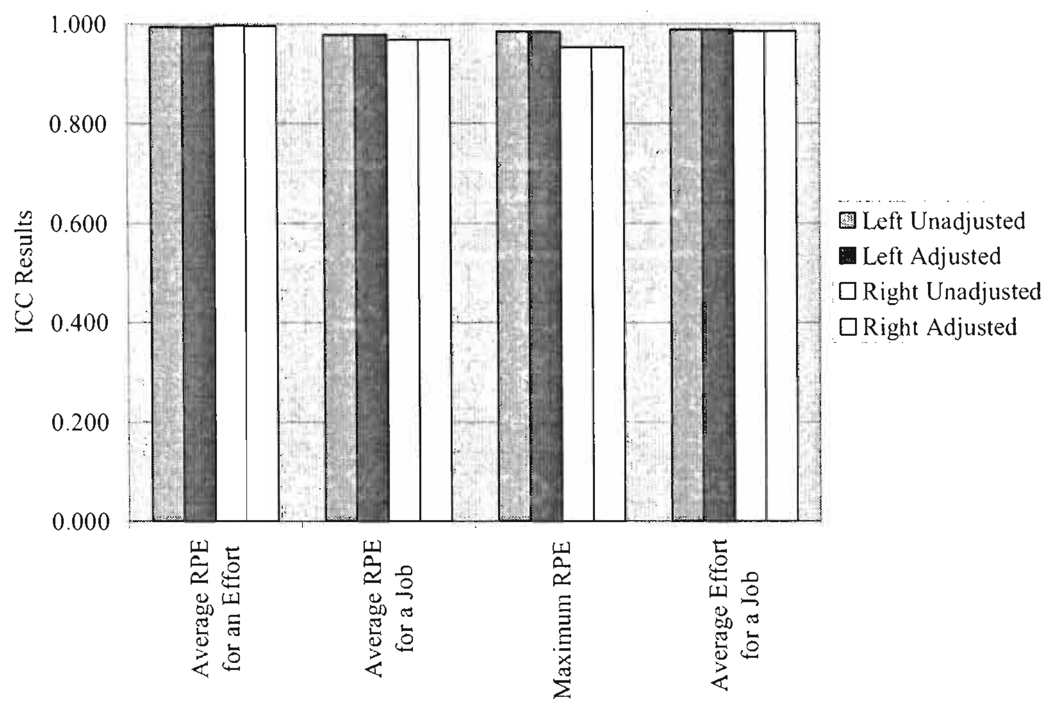

Figure 8: Exertion Level ICC Results

Hand Wrist Posture Results

The hand wrist posture group includes the additional posture categories that were not covered in the posture percentage group. This group includes the average hand wrist posture and the maximum hand wrist posture. The percent difference bar graph for this category can be seen in Figure 9 and the bar graph for the ICC results can be seen in Figure 10.

This category yields fairly low percent differences. The highest percent difference in this group is for the left hand average hand wrist posture at 10.3%. The corresponding ICC for this category on the left hand is 0.894, which is excellent reliability. The greatest percent difference for the right hand is also in the average hand wrist posture category which yields 5.3% and a corresponding ICC of 0.952.

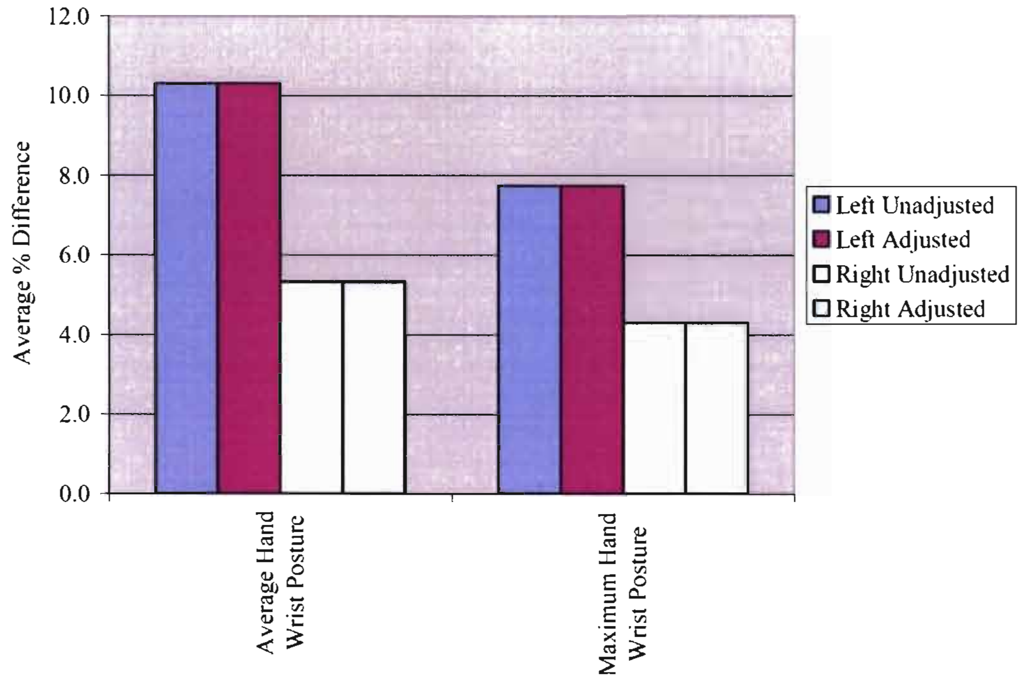

Figure 9: Hand Wrist Posture Percent Difference Results

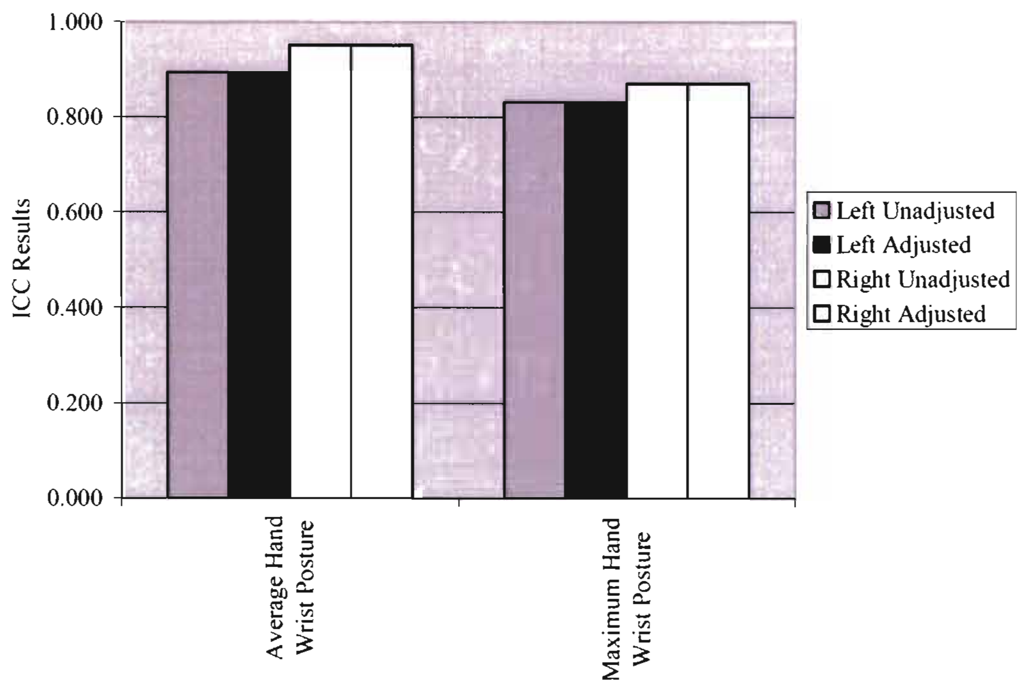

Figure 10: Hand Wrist Posture ICC Results

As explained above, the hand wrist posture group yields very comparable results. Therefore, the built job method is a viable solution for analyzing jobs with regards to the hand wrist posture.

Speed Results

This group includes the three speed categories of interest. It includes the average speed for an effort, the average speed for a job and the maximum speed. A summary of the percent differences for speed can be seen in Figure 11 and the ICC results for speed can be seen in Figure 12.

This category has very comparable data. The average speed for a job has the largest percent difference for this group of 7.1% for the left hand. The corresponding ICC is nearly perfect at 0.977. The right side's average speed for a job has a percent difference of 6.5% and an ICC of 0.940. The two other speed categories have very small percent differences and excellent, or almost perfect, reliabilities.

Overall the built jobs result in very comparable data with regards to the three speed categories analyzed. The percent differences are nearly negligible and all of the speed categories result in an excellent, or almost perfect, reliability.

Categories Affected by Adjusted Built Job Method Results

In order to clearly see the benefit of doing the adjusted built job method, the categories that were improved due to this method are compared in this group. The categories that were improved by the adjusted built job method are the average posture for an effort and efforts per minute. The percent difference results and ICC results bar

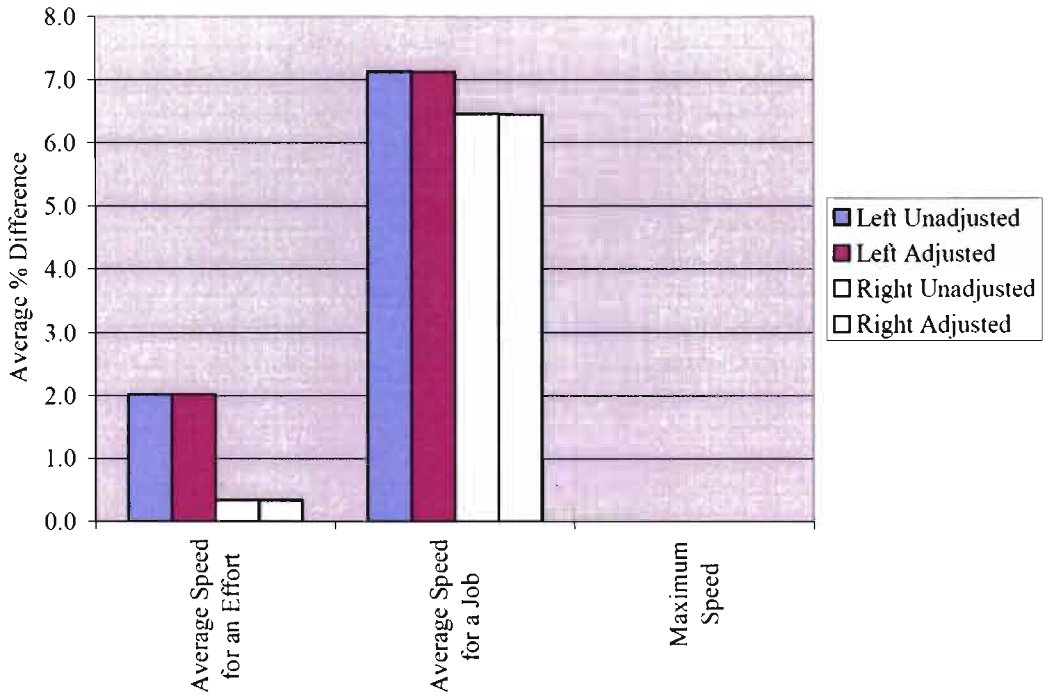

Figure 11: Speed Percent Difference Results

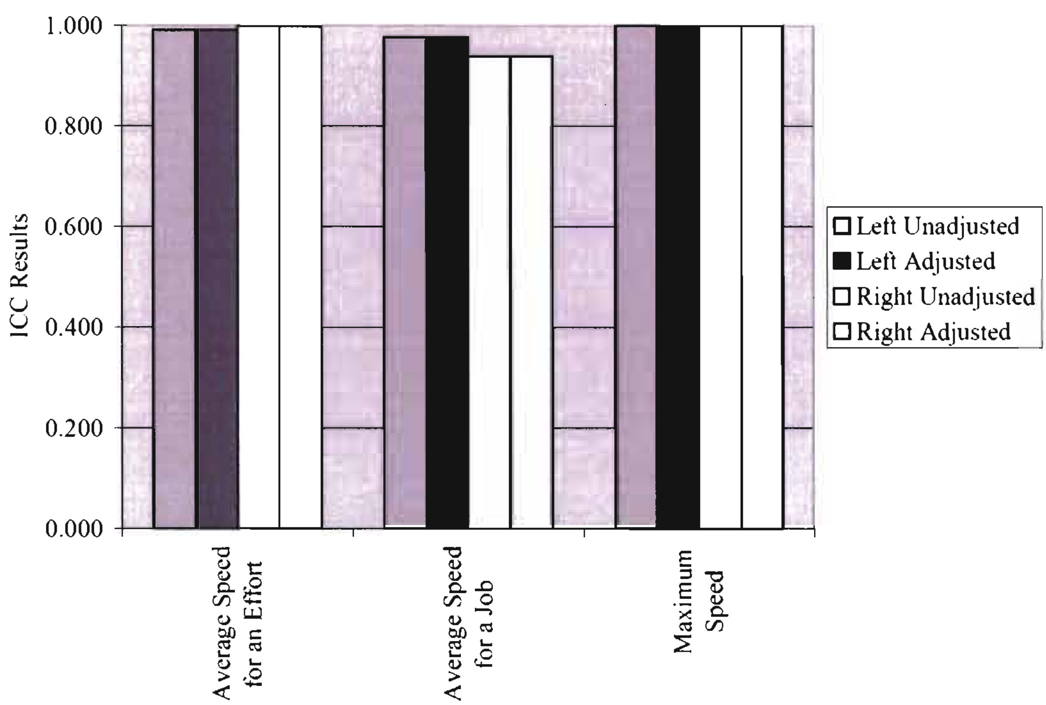

Figure 12: Speed ICC Results

graphs can be seen in Figure 13 and Figure 14.

All of the categories analyzed in this group show improvement. The average posture for an effort shows an improvement for the left hand from 13.0% average difference to 7.1% average difference and an improvement of the ICC values from 0.652 to 0.945. Even though the left hand has great results of 4.7% difference and an ICC of 0.953, no improvements were observed between the unadjusted and adjusted method. The efforts per minute category shows the greatest improvement from a left hand percent difference of 146.4% to 10.9% with an ICC value change of 0.621 to 0.966. The right hand shows an improvement for the efforts per minute category from 31.2% to 23.7% and an ICC value of 0.930 to 0.947.

As described above, the adjusted built job method greatly improved the results with regards to the average posture for an effort and efforts per minute categories. The improved method results in great reductions of the average percent difference and great improvements of the ICC.

Unadjusted Built Job Method Results

Overall, the data shows that the unadjusted built jobs result in good representations of the fully analyzed jobs in all of the categories except average posture for an effort and efforts per minute. These two categories are dependent upon how many distinct efforts are present and the unadjusted method exaggerates the number of "new efforts."

The unadjusted built jobs yield the greatest percent difference for the left hand of

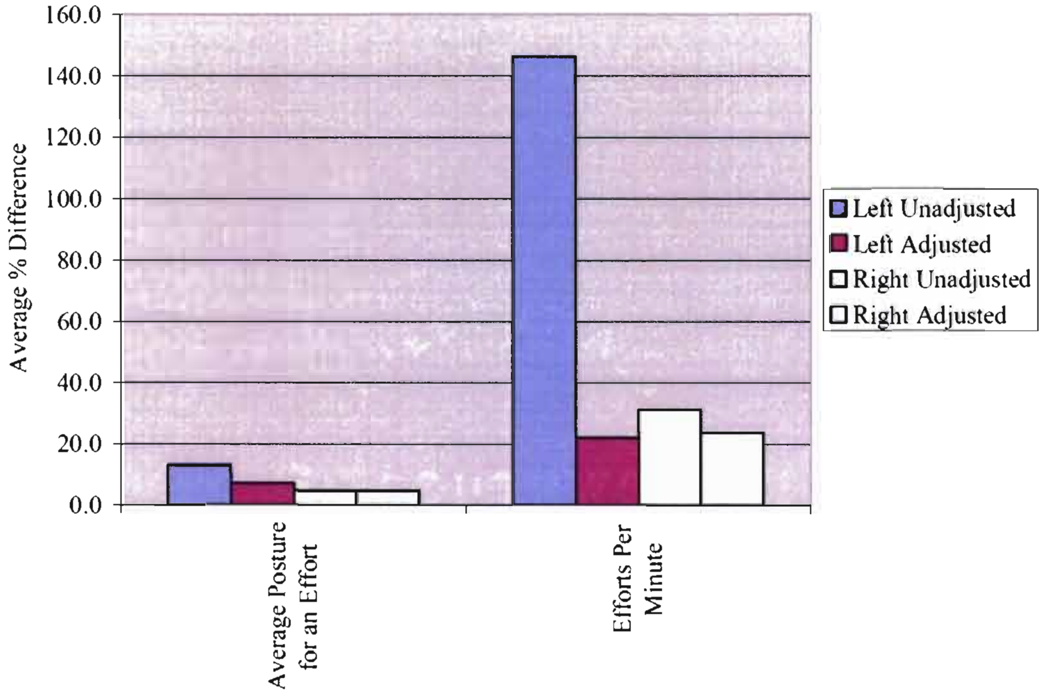

Figure 13: Categories Affected by Adjusted Method Percent Difference Results

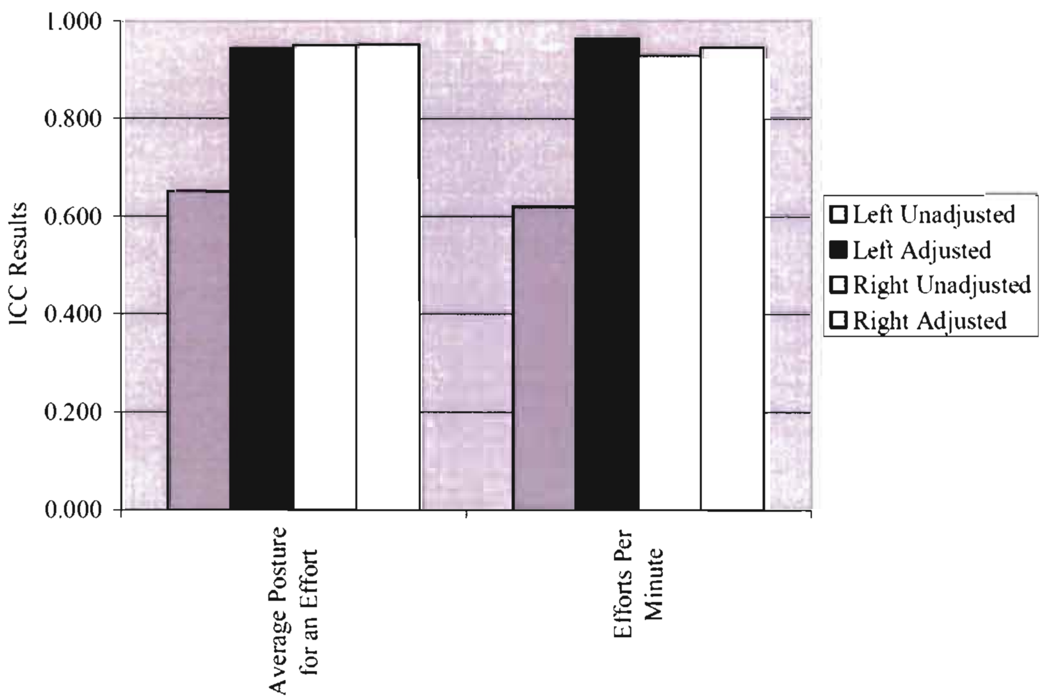

Figure 14: Categories Affected by Adjusted Method ICC Results

146.4% for efforts per minute and a right hand percent difference of 31.2% for efforts per minute. If these categories were disregarded for comparison of the unadjusted built jobs, since they are not correctly accounted for in this method, then this method yields much better results. The maximum percent difference for the left hand would be 16.0% for overall wrist deviation during an effort and 20.0% for overall forearm rotation during an effort for the right hand.

The ICC values for the unadjusted built jobs yield results similar to the percent difference data. The least reliable ICC values found are for the left hand efforts per minute of 0.621 and the right hand maximum hand wrist posture of 0.871. This method does not correct the "effort" versus "new effort" situation. Therefore, if the average posture of an effort and efforts per minute categories were not considered for comparison then the jobs would yield much better ICC's. The left and right hands would have a worst case ICC of 0.832 and 0.871, respectively, for the maximum hand wrist posture. This would yield excellent reliability for both hands.

Adjusted Built Job Method Results

Once the jobs were corrected using the adjusted built job method, the data result in better representations of the fully analyzed jobs.

The adjusted built jobs yield a greatest percent difference for both hands in the category of efforts per minute. The left hand has an efforts per minute percent difference of 22.0% and the right hand has a percent difference of 23.7%. The greatest percent difference for the adjusted built jobs still falls in the efforts per minute category, but shows great improvement from the unadjusted built job method.

The adjusted built jobs also yield good ICC results. The lowest ICC that is found for the left hand is an ICC of 0.939 for the maximum hand wrist posture which yields an excellent, or almost perfect, reliability. An ICC of 0.871 is found for the right side maximum hand wrist posture which yields an excellent, or substantial, reliability.

Time Saving Results

On average, it took analysts about one hour to classify 90 observations, or 900 frames at the skip rate of 10 frames which was used for this research. To clearly see the time savings of "building" jobs, the time required to fully analyze one of the jobs used in this study and the time required to analyze the same job using the built job method will be compared. One of the full jobs used in this research is a total of 3480 frames long which required 348 observations to analyze since analysts classify every 10 frames. When this video was fully analyzed it took approximately 3.87 hours.

When the video was broken down into elements a significant amount of time was saved. It took about 30 minutes to break the video down into elements and document the start and stop frames for each element. The broken down job resulted in only 1660 frames or 166 observations that needed to be classified. This would equate to about 1.84 hours of video classification resulting in a total time of 2.34 hours (0.5 + 1.84) to analyze the same job that took 3.87 hours without building the job. This results in a time saving of 1.53 hours. The built job required only 60% of the time that it took to fully analyze the job.

When the adjusted built job method was implemented a little more documentation was required, but the additional time required was negligible. It only required one note per element and could be easily obtained while watching the video to capture the other information needed to build the job. Therefore, the adjusted built job method added very little additional time up front, but ultimately saved a significant amount of time and resulted in much better representations of the number of efforts and effort derived categories.

CHAPTER 4

DISCUSSION

General Discussion

Overall, both methods, the unadjusted built job method and the adjusted built job method, resulted in representative jobs when compared to the fully analyzed jobs. Therefore, it appeared that hypothesis number one was supported. The adjusted built job method required some additional documentation. However, it greatly improved the results of the two categories that depend on the number of distinct efforts: average posture for an effort and efforts per minute. This suggested that hypothesis number two was supported.

Although most of the results are well within the acceptable range, there are some values that are outside of the desired range. One such category is the efforts per minute category that has greater than 20% average difference even for the adjusted method. A possible source of error that could have contributed to this could be improper choice of element start and stop frames. Since the elements were extracted from the fully analyzed job, the element start and stop frames could have been slightly mistimed. This would lead to a slightly different analysis between the various occurrences of the elements and would have led to some incongruities in the results. Another source of error could have been the skewed camera angle. It could have been a source of error by resulting in different classifications of the same action taking place during different occurrences of the elements. This source could be reduced if multiple cameras were used because it would enable the analyst to better understand the postures and more accurately classify the tasks being completed. However, this would require additional resources that were not available at the time of this study. An earlier phase of this study did employ multiple simultaneous cameras, but resource limitations dictated the use of only one camera for all data analyzed used in this research.

Generally speaking the left hand was affected more by the adjusted built job method. This is interesting because a majority of the people that were analyzed for this study were right handed. This in turn meant that the main action was completed with the subject's right hand, such as placing parts in a bucket, and the left hand was used more as a clamp or fixture, such as holding a bucket.

Posture Percentage During an Effort Discussion

Since the adjusted built job method did not affect the postures, none of the results in this group varied from the unadjusted built job to adjusted built job. Nonetheless, the results for all of the posture percentages were very satisfactory. It could be concluded that the built job, whether adjusted or unadjusted, is an acceptable method for saving time while still obtaining representative posture percentages results for the job of interest. The categories included in this group are important since they characterize posture, which could incorrectly calculate one of the major causes of UECTDs.

Another interesting fact that was noticed while comparing the posture percentage group was that the category that yielded the closest correlation between the built jobs and the fully analyzed jobs was the elbow angle percentage category. This is quite interesting since all of the nonstressful DUE time was classified in one of the two categories, bent arm or straight arm. These two classifications would be strongly driven by the elbow angle percentage. Therefore, the data suggest that the nonstressful DUE time was accounted for relatively accurately.

Exertion Level (Intensity) Discussion

None of the categories in the exertion level group changed from the unadjusted and the adjusted built job method because these categories were not dependent on the effort versus new effort classification. They were only dependent on the level of exertion or intensity.

All of the categories in this group yielded very comparable results from the built jobs to the fully analyzed jobs. This is important since the categories included in this group contribute to one of the major causes to UECTD's, undesirable or high force. If these values were incorrect it could either cause the stress of the tasks completed to appear less stressful, if the values were too low, or cause the tasks to look more stressful, if the values were too high. The built job values of this group are closely representative of the fully analyzed job; therefore, it can be assumed that the jobs analyzed correctly portray the built jobs according to the exertion level required to complete the tasks.

Hand Wrist Posture Discussion

The two categories included in this group are important since they are used to evaluate the stress on the worker with regards to postures required to complete the job. If these categories are incorrectly analyzed then the posture could be incorrectly calculated and result in an incorrect determination of the risk for the job. Therefore, the close representation of the built job and the fully analyzed job indicate that building jobs is a useful method for determining the hand wrist posture of a job. Since these values are solely dependent upon the postures there is no difference between the unadjusted and the adjusted built job method.

Speed Discussion

All speed categories included in this group result in excellent results. These categories are important because they factor into how much effort a job takes. If the speeds were over estimated then a job could appear more tiring than it really is. If the speeds were under estimated then a job could appear less tiring than it really is. Therefore, since the built job's speed results are very representative of the fully analyzed jobs, the speed will not be a contributing factor to error of analysis if the built job method is used.

Categories Affected by Adjusted Built Job Method Discussion

As shown in the results section, the adjusted method greatly reduces the average percent difference as well as greatly increases the ICC for the average posture for an effort and efforts per minute. These are two very important categories since they all contribute to the evaluation of the stress for the jobs.

The average posture for an effort classifies the posture present during an effort. The posture is directly related to the hazard of a job since it is one of the big risk factors.

Since this category classifies the posture during an effort this is even more critical because the time spent completing an effort greatly affects the stress on a worker. The posture spent completing nonstressful DUE activities is not as influential on the overall stress of the job. Therefore, the results of this category are important for the end results and the adjusted method should be implemented to obtain refined values for this category.

Efforts per minute is another category that greatly affects the evaluation of the stress on a worker completing a job. This category ties into two of the big risk factors, high rate of repetition and long durations without adequate rest. The efforts per minute values are used to determine the rate at which efforts are completed and thus can be converted to the rate of repetition. Efforts per minute are also indirectly related to the length of durations and could be evaluated to determine the amount of rest taken in relation to the amount of time spent completing an effort.

Unadjusted Built Job Method Discussion

Overall, the unadjusted built job method yields very reliable results in all of the categories except average posture for an effort and efforts per minute. The values of these two categories are not as reliable as the rest of the data for this method.

Although most of the categories yield reliable results for the unadjusted built job method it would be beneficial to complete the adjusted built job method. It requires very little additional effort and yields much more representative results for the two categories corrected by the adjusted built job method.

Adjusted Built Job Method Discussion

It can be seen that only two values are affected by the adjusted built job method. However, since these values are very indicative of the stress related with the job, it can be seen that the adjusted built job method is very beneficial. All of the values in these two categories show improvement. Although some categories only yield small improvements, other categories such as efforts per minute are greatly improved. The efforts per minute percent difference for the left hand is improved by approximately seven times from 146.4% to 22.0%. This is a substantial improvement and helps to reiterate why the improved method has great benefits.

Time Saving Discussion

As mentioned earlier, there are some videos that are longer than one hour. This would equate to over 120 hours of video analysis. The overall study has multiple jobs with durations in excess of one hour. If these videos were analyzed without employing the built job method, then a considerable amount of resources would be required. However, with the implementation of the built job method, a substantial amount of time will be saved and the effort can be use for other tasks. Overall, this research shows that the built job method is a great opportunity to obtain reliable data yet saves a substantial amount of time.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Ultimately, the built jobs result in a good representation of the fully analyzed jobs. All of the jobs analyzed yield approximately a 24% difference or better. All of the ICC calculations show that there was an excellent, or almost perfect, reliability between the built jobs and the fully analyzed jobs. Therefore, the percent differences as well as the ICCs show that building jobs is an acceptable method for analyzing jobs and should be used to save time.

As predicted, the adjusted built jobs yield better results than the unadjusted built jobs. There are some categories that are not affected by the adjusted method, but the results of other categories are drastically changed. Therefore, the adjusted built job method should be employed while building jobs to get a better representation of the fully analyzed job.

Recommendations

While completing this research some areas that could be improved upon were discovered. If these areas were researched in more depth, then more information could be provided about the larger study that is being completed. Some of the more crucial ideas that were discovered are discussed.

Although this research yields good results, it only included shorter cycles. It is assumed that this method could be employed for any length of a job and would still yield results similar to those found in this research. However, since longer cycles, such as 5 minutes or longer, were not analyzed it would be beneficial to verify that they behave in the same manner as the shorter cycles analyzed in this research.

The data used for this research were gathered from analysts that were thoroughly trained and experienced using the UTEA analysis program. However, since the built jobs were only analyzed once for this study there is no data that are available to check its repeatability. In order to enhance the usefulness of this research an intrarater reliability analysis should be completed. This would include having a single analyst complete the analysis of the complete jobs as well as the elements within the jobs a total of two or more times. The multiple element analyses would then be used to build multiple built jobs which could be compared to the multiple analyses of the complete job. This would give the reliability and repeatability of the analyst.

In the interest of time and at due to limited resources (analyst time), the built jobs were composed of pieces pulled from the fully analyzed job. It would be interesting to see if the built jobs would yield similar results if the built jobs were composed of individually analyzed elements. One problem that may arise with this comparison would be that the classification of the job during the whole video analysis and the classification of the individual elements contained in the whole job may not be analyzed exactly the same. If this were to happen, the variation in analysis of the exact same frames would already show differences without comparing the built job method. Therefore, this method could show a weaker correlation between the built jobs and the fully analyzed jobs solely due to the limited repeatability of analysis. Further research is required to shed light on this important area.

For this research nonstressful DUE activities were classified into two different categories, bent arm and straight arm postures. The results of this study did provide promising results that this was an adequate method for handling nonstressful DUE activities. However, it would be interesting to see how the jobs would compare if the nonstressful DUE activities were analyzed frame by frame. This would require more time since essentially it would mean that more elements would need to be analyzed, but it would be beneficial to verify that there is little, if any, difference.

For this study, the elements were not placed in a specific order when building the built jobs. All of the occurrences for element one were placed, then all of the occurrences for element two were placed and so on for all of the elements. Then the nonstressful DUE elements were placed at the end to equalize the built job length to the fully analyzed job length. This should not affect the end results since the calculations completed are not order dependent, rather they are dependent simply upon whether or not they occur. However, to determine if element order affects the results this would be a good area for future research.

One final recommendation for further research would be to build the jobs for the left and right hands individually. This would require that each hand be reviewed and the elements for each hand documented individually. The need to implement the adjusted method would not be needed since the effort versus new effort situation would not arise.

However, this would require roughly twice the time to complete. Although this method may yield better results than the adjusted built method used in this research, a significantly larger amount of time would be required.

APPENDIX A

UTEA OUTPUTS

Table 5: UTEA Outputs

OUTPUT	DESCRIPTION
Subject	Assigned Subject Number
Position Number	Assigned Position Number
Job Number	Assigned Job Number
Element Number	Assigned Element Number
Entry #	Consecutive Entry Number
Final Entry #	Total or Final Entry Number
Frame #	Video Frame Number
Frame Rate	Frame Skip Rate Used
Duration	Time Spent Between Entries
Left Side Comments	Left Side Comments
Left Effort Number	Left Type of Activity (i.e. New Effort/Effort/Idle)
Left Borg Level	Left RPE Level at Observation
Left Effort Speed	Left Effort Speed at Observation
Right Side Comments	Right Side Comments
Right Effort Number	Right Type of Activity (i.e. New Effort/Effort/Idle)
Right Borg Level	Right RPE Level at Observation
Right Effort Speed	Right Effort Speed at Observation
Neck Rotation	Neck Rotation at Observation
Neck Tilt	Neck Tilt at Observation
Neck Lateral Flexion	Neck Lateral Flexion at Observation
Back Bend	Back Bend at Observation
Back Twist	Back Twist at Observation
Back Lateral Flexion	Back Lateral Flexion at Observation
LF Elb Ang	Left Elbow Angle at Observation
LF FArm Rot	Left Forearm Rotation at Observation
LF Elb Comp	Left Elbow Compression at Observation
LF FArm Comp	Left Forearm Compression at Observation
LF Flx/Ext	Left Flexion/Extension at Observation
LF Dev	Left Wrist Deviation at Observation
LF Wrst Comp	Left Wrist Compression at Observation
LF Grip	Left Grip at Observation
LF Kick	Left Kick at Observation
LF Ham	Left Hammer at Observation
LF Hand Comp	Left Hand Compression at Observation
LF Vib	Left Vibration at Observation
LF Fing Comp	Left Finger Compression at Observation
LT Shldr Flx/Ext	Left Shoulder Flexion/Extension at Observation
LT Shldr Abduction	Left Shoulder Abduction at Observation
LT Shldr Rotation	Left Shoulder Rotation at Observation
LT Shldr Elevation	Left Shoulder Elevation at Observation
LT Shldr Effort	Left Shoulder Effort at Observation
LT Shldr Borg	Left Shoulder RPE at Observation
LT Shldr Speed	Left Shoulder Speed at Observation
LT Posture	Left Posture at Observation

Table 5 Continued

OUTPUT	DESCRIPTION
RT Elb Ang	Right Elbow Angle at Observation
RT FArm Rot	Right Forearm Rotation at Observation
RT Elb Comp	Right Elbow Compression at Observation
RT FArm Comp	Right Forearm Compression at Observation
RT Flx/Ext	Right Flexion/Extension at Observation
RT Dev	Right Wrist Deviation at Observation
RT Wrst Comp	Right Wrist Compression at Observation
RT Grip	Right Grip at Observation
RT Kick	Right Kick at Observation
RT Ham	Right Hammer at Observation
RT Hand Comp	Right Hand Compression at Observation
RT Vib	Right Vibration at Observation
RT Fing Comp	Right Finger Compression at Observation
RT Shldr Flx/Ext	Right Shoulder Flexion/Extension at Observation
RT Shldr Abduction	Right Shoulder Abduction at Observation
RT Shldr Rotation	Right Shoulder Rotation at Observation
RT Shldr Elevation	Right Shoulder Elevation at Observation
RT Shldr Effort	Right Shoulder Effort at Observation
RT Shldr Borg	Right Shoulder RPE at Observation
RT Shldr Speed	Right Shoulder Speed at Observation
RT Posture	Right Posture at Observation
Time Stamp	Time Stamp at Observation

APPENDIX B

EAC OUTPUTS

Table 6: EAC Outputs – Left and Right Compiled Max Force Tab

Left Output	Right Output	Description
Subject	Subject	Assigned Subject Number
Position Number	Position Number	Assigned Position Number
Job Number	Job Number	Assigned Job Number
Time	Time	Total Analysis Time
LtLwFlxExp_total	RtLwFlxExp_total	Low Flexion % for the Job
LtLwFlxCnt_change	RtLwFlxCnt_change	# of Times changed into Low Flexion
LtLwFlxExp_effort	RtLwFlxExp_effort	Low Flexion % During an Effort
LtLwFlxCnt_NEW_effort	RtLwFlxCnt_NEW_effort	# Low Flexion Occurrences at Start of New Effort
LtLwFlxExp_idle	RtLwFlxExp_idle	Low Flexion % During Idle
LtLwFlxMF	RtLwFlxMF	Maximum Force Observed in Low Flexion
LtMdFlxExp_total	RtMdFlxExp_total	Moderate Flexion % for the job
LtMdFlxCnt_change	RtMdFlxCnt_change	# of Times changed into Moderate Flexion
LtMdFlxExp_effort	RtMdFlxExp_effort	Moderate Flexion % During an Effort
LtMdFlxCnt_NEW_effort	RtMdFlxCnt_NEW_effort	# Moderate Flexion Occurrences at Start of New Effort
LtMdFlxExp_idle	RtMdFlxExp_idle	Moderate Flexion % During Idle
LtMdFlxMF	RtMdFlxMF	Maximum Force Observed in Moderate Flexion
LtHhFlxExp_total	RtHhFlxExp_total	High Flexion % for the Job
LtHhFlxCnt_change	RtHhFlxCnt_change	# of Times changed into High Flexion
LtHhFlxExp_effort	RtHhFlxExp_effort	High Flexion % During an Effort
LtHhFlxCnt_NEW_effort	RtHhFlxCnt_NEW_effort	# High Flexion Occurrences at Start of New Effort
LtHhFlxExp_idle	RtHhFlxExp_idle	High Flexion % During Idle
LtHhFlxMF	RtHhFlxMF	Maximum Force Observed in High Flexion
LtLwExtExp_total	RtLwExtExp_total	Low Extension % for the Job
LtLwExtCnt_change	RtLwExtCnt_change	# of Times changed into Low Extension
LtLwExtExp_effort	RtLwExtExp_effort	Low Extension % During an Effort
LtLwExtCnt_NEW_effort	RtLwExtCnt_NEW_effort	# Low Extension Occurrences at Start of New Effort
LtLwExtExp_idle	RtLwExtExp_idle	Low Extension % During Idle
LtLwExtMF	RtLwExtMF	Maximum Force Observed in Low Extension
LtMdExtExp_total	RtMdExtExp_total	Moderate Extension % for the Job
LtMdExtCnt_change	RtMdExtCnt_change	# of Times changed into Moderate Extension
LtMdExtExp_effort	RtMdExtExp_effort	Moderate Extension % During an Effort
LtMdExtCnt_NEW_effort	RtMdExtCnt_NEW_effort	# Mod. Extension Occurrences at Start of New Effort
LtMdExtExp_idle	RtMdExtExp_idle	Moderate Extension % During Idle
LtMdExtMF	RtMdExtMF	Maximum Force Observed in Moderate Extension
LtHhExtExp_total	RtHhExtExp_total	High Extension % for the Job
LtHhExtCnt_change	RtHhExtCnt_change	# of Times changed into High Extension
LtHhExtExp_effort	RtHhExtExp_effort	High Extension % During an Effort
LtHhExtCnt_NEW_effort	RtHhExtCnt_NEW_effort	# High Extension Occurrences at Start of New Effort
LtHhExtExp_idle	RtHhExtExp_idle	High Extension % During Idle
LtHhExtMF	RtHhExtMF	Maximum Force Observed in High Extension

Table 6 Continued

Left Output	Right Output	Description
LtNeutDExp_total	RtNeutDExp_total	Neutral Deviation % for the Job
LtNeutDCnt_change	RtNeutDCnt_change	# of Times changed into Neutral Deviation
LtNeutDExp_effort	RtNeutDExp_effort	Neutral Deviation % During an Effort
LtNeutDCnt_NEW_effort	RtNeutDCnt_NEW_effort	# Neutral Deviation Occurrences at Start of New Effort
LtNeutDMF	RtNeutDMF	Maximum Force Observed in Neutral Deviation
LtMdUDExp_total	RtMdUDExp_total	Moderate Ulnar Deviation % for the Job
LtMdUDCnt_change	RtMdUDCnt_change	# of Times changed into Moderate Ulnar Deviation
LtMdUDExp_effort	RtMdUDExp_effort	Moderate Ulnar Deviation % During an Effort
LtMdUDCnt_NEW_effort	RtMdUDCnt_NEW_effort	# Mod. Ulnar Deviation Occurrences at Start of New Effort
LtMdUDMF	RtMdUDMF	Maximum Force Observed in Moderate Ulnar Deviation
LtHhUDExp_total	RtHhUDExp_total	High Ulnar Deviation % for the Job
LtHhUDCnt_change	RtHhUDCnt_change	# of Times changed into High Ulnar Deviation
LtHhUDExp_effort	RtHhUDExp_effort	High Ulnar Deviation % During an Effort
LtHhUDCnt_NEW_effort	RtHhUDCnt_NEW_effort	# High Ulnar Deviation Occurrences at Start of New Effort
LtHhUDMF	RtHhUDMF	Maximum Force Observed in High Ulnar Deviation
LtRDExp_total	RtRDExp_total	Radial Deviation % for the Job
LtRDCnt_change	RtRDCnt_change	# of Times changed into Radial Deviation
LtRDExp_effort	RtRDExp_effort	Radial Deviation % During an Effort
LtRDCnt_NEW_effort	RtRDCnt_NEW_effort	# Radial Deviation Occurrences at Start of New Effort
LtRDMF	RtRDMF	Maximum Force Observed in Radial Deviation
LtPrntExp_total	RtPrntExp_total	Pronated % for the Job
LtPrntCnt_change	RtPrntCnt_change	# of Times changed into Pronation
LtPrntExp_effort	RtPrntExp_effort	Pronated % During an Effort
LtPrntCnt_NEW_effort	RtPrntCnt_NEW_effort	# Pronation Occurrences at Start of New Effort
LtPrntMF	RtPrntMF	Maximum Force Observed in Pronation
LtNtrlExp_total	RtNtrlExp_total	Neutral % for the Job
LtNtrlCnt_change	RtNtrlCnt_change	# of Times changed into Neutral Forearm Rotation
LtNtrlExp_effort	RtNtrlExp_effort	Neutral % During an Effort
LtNtrlCnt_NEW_effort	RtNtrlCnt_NEW_effort	# Neut. Forearm Rot. Occurrences at Start of New Effort
LtNtrlMF	RtNtrlMF	Maximum Force Observed in Neutral Forearm Rotation
LtSpnExp_total	RtSpnExp_total	Supinated % for the Job
LtSpnCnt_change	RtSpnCnt_change	# of Times changed into Supination
LtSpnExp_effort	RtSpnExp_effort	Supinated % During an Effort
LtSpnCnt_NEW_effort	RtSpnCnt_NEW_effort	# Supination Occurrences at Start of New Effort
LtSpnMF	RtSpnMF	Maximum Force Observed in Supination
LtRotCnt	RtRotCnt	Forearm Rotation Count
Lt135Exp_total	Rt135Exp_total	>135 Elbow Angle % for the Job
Lt135Cnt_change	Rt135Cnt_change	# of Times changed into >135 Elbow Angle
Lt135Exp_effort	Rt135Exp_effort	>135 Elbow Angle % During an Effort
Lt135Cnt_NEW_effort	Rt135Cnt_NEW_effort	# >135 Elbow Angle Occurrences at Start of New Effort
Lt135MF	Rt135MF	Maximum Force Observed in >135 Elbow Angle

Table 6 Continued

Left Output	Right Output	Description
LtElbExp_total	RtElbExp_total	Neutral Elbow Angle % for the Job
LtElbCnt_change	RtElbCnt_change	# of Times changed into Neutral Elbow Angle
LtElbExp_effort	RtElbExp_effort	Neutral Elbow Angle % During an Effort
LtElbCnt_NEW_effort	RtElbCnt_NEW_effort	# Neut. Elbow Angle Occurrences at Start of New Effort
LtElbMF	RtElbMF	Maximum Force Observed in Neutral Elbow Angle
Lt70Exp_total	Rt70Exp_total	<70 Elbow Angle % for the Job
Lt70Cnt_change	Rt70Cnt_change	# of Times changed into <70 Elbow Angle
Lt70Exp_effort	Rt70Exp_effort	<70 Elbow Angle % During an Effort
Lt70Cnt_NEW_effort	Rt70Cnt_NEW_effort	# <70 Elbow Angle Occurrences at Start of New Effort
Lt70MF	Rt70MF	Maximum Force Observed in <70 Elbow Angle
LtPwrHkExp_total	RtPwrHkExp_total	Power Hook Grip % for the Job
LtPwrHkCnt_change	RtPwrHkCnt_change	# of Times changed into Power Hook Grip
LtPwrHkExp_effort	RtPwrHkExp_effort	Power Hook Grip % During an Effort
LtPwrHkCnt_NEW_effort	RtPwrHkCnt_NEW_effort	# Power Hook Grip Occurrences at Start of New Effort
LtPwrHkMF	RtPwrHkMF	Maximum Force Observed in Power Hook Grip
LtOblqExp_total	RtOblqExp_total	Oblique Grip % for the Job
LtOblqCnt_change	RtOblqCnt_change	# of Times changed into Oblique Grip
LtOblqExp_effort	RtOblqExp_effort	Oblique Grip % During an Effort
LtOblqCnt_NEW_effort	RtOblqCnt_NEW_effort	# Oblique Grip Occurrences at Start of New Effort
LtOblqMF	RtOblqMF	Maximum Force Observed in Oblique Grip
LtPlmrGrpExp_total	RtPlmrGrpExp_total	Palmer Grip % for the Job
LtPlmrGrpCnt_change	RtPlmrGrpCnt_change	# of Times changed into Palmer Grip
LtPlmrGrpExp_effort	RtPlmrGrpExp_effort	Palmer Grip % During an Effort
LtPlmrGrpCnt_NEW_effort	RtPlmrGrpCnt_NEW_effort	# Palmer Grip Occurrences at Start of New Effort
LtPlmrGrpMF	RtPlmrGrpMF	Maximum Force Observed in Palmer Grip
LtPlmrPnchExp_total	RtPlmrPnchExp_total	Palmer Pinch % for the Job
LtPlmrPnchCnt_change	RtPlmrPnchCnt_change	# of Times changed into Palmer Pinch
LtPlmrPnchExp_effort	RtPlmrPnchExp_effort	Palmer Pinch % During an Effort
LtPlmrPnchCnt_NEW_effort	RtPlmrPnchCnt_NEW_effort	# Palmer Pinch Occurrences at Start of New Effort
LtPlmrPnchMF	RtPlmrPnchMF	Maximum Force Observed in Palmer Pinch
LtPntPnchExp_total	RtPntPnchExp_total	2 or 3 Point Pinch % for the Job
LtPntPnchCnt_change	RtPntPnchCnt_change	# of Times changed into 2 or 3 Point Pinch
LtPntPnchExp_effort	RtPntPnchExp_effort	2 or 3 Point Pinch % During an Effort
LtPntPnchCnt_NEW_effort	RtPntPnchCnt_NEW_effort	# 2 or 3 Point Pinch Occurrences at Start of New Effort
LtPntPnchMF	RtPntPnchMF	Maximum Force Observed in 2 or 3 Point Pinch
LtKyPnchExp_total	RtKyPnchExp_total	Key Pinch % for the Job
LtKyPnchCnt_change	RtKyPnchCnt_change	# of Times changed into Low Flexion
LtKyPnchExp_effort	RtKyPnchExp_effort	Key Pinch % During an Effort
LtKyPnchCnt_NEW_effort	RtKyPnchCnt_NEW_effort	# Key Pinch Occurrences at Start of New Effort
LtKyPnchMF	RtKyPnchMF	Maximum Force Observed in Key Pinch

Table 6 Continued

Left Output	Right Output	Description
LtCntctExp_total	RtCntctExp_total	Contact Grip % for the Job
LtCntctCnt_change	RtCntctCnt_change	# of Times changed into Key Pinch
LtCntctExp_effort	RtCntctExp_effort	Contact Grip % During an Effort
LtCntctCnt_NEW_effort	RtCntctCnt_NEW_effort	# Contact Grip Occurrences at Start of New Effort
LtCntctMF	RtCntctMF	Maximum Force Observed in Contact Grip
LtNoGrpExp	RtNoGrpExp	No Grip % for the Job
LtNoGrpCnt_change	RtNoGrpCnt_change	# of Times changed into No Grip
LtMFngCmpExp_total	RtMFngCmpExp_total	Moderate Finger Compression % for the Job
LtMFngCmpCnt_change	RtMFngCmpCnt_change	# of Times changed into Moderate Finger Compression
LtMFngCmpExp_effort	RtMFngCmpExp_effort	Moderate Finger Compression % During an Effort
LtMFngCmpCnt_NEW_effort	RtMFngCmpCnt_NEW_effort	# Mod. Finger Comp. Occurrences at Start of New Effort
LtMFngCmpMF	RtMFngCmpMF	Max Force Observed in Moderate Finger Compression
LtSFngCmpExp_total	RtSFngCmpExp_total	Severe Finger Compression % for the Job
LtSFngCmpCnt_change	RtSFngCmpCnt_change	# of Times changed into Severe Finger Compression
LtSFngCmpExp_effort	RtSFngCmpExp_effort	Severe Finger Compression % During an Effort
LtSFngCmpCnt_NEW_effort	RtSFngCmpCnt_NEW_effort	# Severe Finger Comp. Occurrences at Start of New Effort
LtSFngCmpMF	RtSFngCmpMF	Maximum Force Observed in Severe Finger Compression
LtMHndCmpExp_total	RtMHndCmpExp_total	Moderate Hand Compression % for the Job
LtMHndCmpCnt_change	RtMHndCmpCnt_change	# of Times changed into Moderate Hand Compression
LtMHndCmpExp_effort	RtMHndCmpExp_effort	Moderate Hand Compression % During an Effort
LtMHndCmpCnt_NEW_effort	RtMHndCmpCnt_NEW_effort	# Mod. Hand Comp. Occurrences at Start of New Effort
LtMHndCmpMF	RtMHndCmpMF	Max Force Observed in Moderate Hand Compression
LtSHndCmpExp_total	RtSHndCmpExp_total	Severe Hand Compression % for the Job
LtSHndCmpCnt_change	RtSHndCmpCnt_change	# of Times changed into Severe Hand Compression
LtSHndCmpExp_effort	RtSHndCmpExp_effort	Severe Hand Compression % During an Effort
LtSHndCmpCnt_NEW_effort	RtSHndCmpCnt_NEW_effort	# Severe Hand Comp. Occurrences at Start of New Effort
LtSHndCmpMF	RtSHndCmpMF	Maximum Force Observed in Severe Hand Compression
LtMWrstCmpExp_total	RtMWrstCmpExp_total	Moderate Wrist Compression % for the Job
LtMWrstCmpCnt_change	RtMWrstCmpCnt_change	# of Times changed into Moderate Wrist Compression
LtMWrstCmpExp_effort	RtMWrstCmpExp_effort	Moderate Wrist Compression % During an Effort
LtMWrstCmpCnt_NEW_effort	RtMWrstCmpCnt_NEW_effort	# Mod. Wrist Comp. Occurrences at Start of New Effort
LtMWrstCmpMF	RtMWrstCmpMF	Max Force Observed in Moderate Wrist Compression
LtSWrstCmpExp_total	RtSWrstCmpExp_total	Severe Wrist Compression % for the Job
LtSWrstCmpCnt_change	RtSWrstCmpCnt_change	# of Times changed into Severe Wrist Compression
LtSWrstCmpExp_effort	RtSWrstCmpExp_effort	Severe Wrist Compression % During an Effort
LtSWrstCmpCnt_NEW_effort	RtSWrstCmpCnt_NEW_effort	# Severe Wrist Comp. Occurrences at Start of New Effort
LtSWrstCmpMF	RtSWrstCmpMF	Maximum Force Observed in Severe Wrist Compression

Table 6 Continued

Left Output	Right Output	Description
LtMFArmCmpExp_total	RtMFArmCmpExp_total	Moderate Forearm Compression % for the Job
LtMFArmCmpCnt_change	RtMFArmCmpCnt_change	# of Times changed into Moderate Forearm Compression
LtMFArmCmpExp_effort	RtMFArmCmpExp_effort	Moderate Forearm Compression % During an Effort
LtMFArmCmpCnt_NEW_effort	RtMFArmCmpCnt_NEW_effort	# Mod. Forearm Comp. Occurrences at Start of New Effort
LtMFArmCmpMF	RtMFArmCmpMF	Max Force Observed in Moderate Forearm Compression
LtSFArmCmpExp_total	RtSFArmCmpExp_total	Severe Forearm Compression % for the Job
LtSFArmCmpCnt_change	RtSFArmCmpCnt_change	# of Times changed into Severe Forearm Compression
LtSFArmCmpExp_effort	RtSFArmCmpExp_effort	Severe Forearm Compression % During an Effort
LtSFArmCmpCnt_NEW_effort	RtSFArmCmpCnt_NEW_effort	# Severe Forearm Comp. Occurrences at Start of New Effort
LtSFArmCmpMF	RtSFArmCmpMF	Max Force Observed in Severe Forearm Compression
LtMElbCmpExp_total	RtMElbCmpExp_total	Moderate Elbow Compression % for the Job
LtMElbCmpCnt_change	RtMElbCmpCnt_change	# of Times changed into Moderate Elbow Compression
LtMElbCmpExp_effort	RtMElbCmpExp_effort	Moderate Elbow Compression % During an Effort
LtMElbCmpCnt_NEW_effort	RtMElbCmpCnt_NEW_effort	# Mod. Elbow Comp. Occurrences at Start of New Effort
LtMElbCmpMF	RtMElbCmpMF	Max Force Observed in Moderate Elbow Compression
LtSElbCmpExp_total	RtSElbCmpExp_total	Severe Elbow Compression % for the Job
LtSElbCmpCnt_change	RtSElbCmpCnt_change	# of Times changed into Severe Elbow Compression
LtSElbCmpExp_effort	RtSElbCmpExp_effort	Severe Elbow Compression % During an Effort
LtSElbCmpCnt_NEW_effort	RtSElbCmpCnt_NEW_effort	# Severe Elbow Comp. Occurrences at Start of New Effort
LtSElbCmpMF	RtSElbCmpMF	Maximum Force Observed in Severe Elbow Compression
LtMKckCnt	RtMKckCnt	Moderate Kick Count
LtSKckCnt	RtSKckCnt	Severe Kick Count
LtMHmmCnt	RtMHmmCnt	Moderate Hammer Count
LtSHmmCnt	RtSHmmCnt	Severe Hammer Count
LtMVbrExp	RtMVbrExt	Moderate Vibration Exposure
LtSVbrExp	RtSVbrExp	Severe Vibration Exposure

Table 7: EAC Outputs – GARF Compiled Effort Tab

OUTPUT	DESCRIPTION
Subject	Assigned Subject Number
Position Number	Assigned Position Number
Job Number	Assigned Job Number
Side	Left or Right Side
Time (secs)	Total Analysis Time
Task #	Sequential Task Number
Avg Borg	Average RPE
Max Borg	Maximum RPE
# in Cycle	Default of One Effort per Cycle
Avg Posture	Average Posture
Max Posture	Maximum Posture
Duration	Duration of Effort
Avg Speed	Average Speed
Max Speed	Maximum Speed
Frames	Frame Length of Effort

Table 8: EAC Outputs – GARF Stain Index Tab

OUTPUT	DESCRIPTION
Subject	Assigned Subject Number
Position Number	Assigned Position Number
Job Number	Assigned Job Number
Side	Left or Right Side
Time (secs)	Total Analysis Time
Job Avg Borg	Average RPE for the Job
Job Avg Effort	Average Effort for the Job
Max Borg	Maximum RPE for the Job
Duration of Exertions	Duration of Exertions
Efforts/min	Efforts per Minute
Avg Hand/Wrist Posture	Average Hand/Wrist Posture
Max Hand/Wrist Posture	Maximum Hand/Wrist Posture
Avg Speed	Average Speed
Effort Avg Speed	Average Speed During an Effort
Max Speed	Maximum Speed
Hand Activity Level	Hand Activity Level
Frame Count	Number of Observations
Skip Rate	Frame Skip Rate Used

APPENDIX C

AVERAGES, STANDARD DEVIATIONS, PERCENT DIFFERENCES OF AVERAGES AND AVERAGE PERCENT DIFFERENCES OF UNADJUSTED, ADJUSTED AND FULL DATA

Table 9: Forearm Rotation Statistical Summary

	Overall Forearm Rotation Percentage									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.333	0.333	0.333			0.333	0.333	0.333		
STDEV	0.380	0.380	0.380			0.364	0.364	0.359		
% Diff	0.000	0.000	N/A	11.512	11.512	0.000	0.000	N/A	20.020	20.020

	Pronated Forearm Rotation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.355	0.355	0.346			0.426	0.426	0.440		
STDEV	0.355	0.355	0.350			0.335	0.335	0.334		
% Diff	2.707	2.707	N/A	17.115	17.115	3.218	3.218	N/A	36.262	36.262

	Neutral Forearm Rotation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.615	0.615	0.622			0.571	0.571	0.552		
STDEV	0.360	0.360	0.358			0.339	0.339	0.335		
% Diff	1.241	1.241	N/A	7.714	7.714	3.538	3.538	N/A	19.506	19.506

	Supinated Forearm Rotation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.030	0.030	0.032			0.003	0.003	0.009		
STDEV	0.098	0.098	0.105			0.018	0.018	0.033		
% Diff	5.187	5.187	N/A	9.707	9.707	61.998	61.998	N/A	4.292	4.292

Table 10: Elbow Angle Statistical Summary

	Overall Elbow Angle Percentage									
	Left					**Right**				
	Unadjusted	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**	**Unadjusted**	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**
AVE	**0.326**	**0.326**	**0.326**			**0.326**	**0.326**	**0.326**		
STDEV	**0.401**	**0.401**	**0.397**			**0.361**	**0.361**	**0.365**		
% Diff	**0.000**	**0.000**	**N/A**	**11.227**	**11.227**	**0.000**	**0.000**	**N/A**	**8.693**	**8.693**

	<70 Elbow Angle Percentage for an Effort									
	Left					**Right**				
	Unadjusted	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**	**Unadjusted**	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**
AVE	**0.011**	**0.011**	**0.012**			**0.011**	**0.011**	**0.009**		
STDEV	**0.031**	**0.031**	**0.030**			**0.029**	**0.029**	**0.026**		
% Diff	**0.913**	**0.913**	**N/A**	**10.996**	**10.996**	**14.431**	**14.431**	**N/A**	**4.833**	**4.833**

	Neutral Elbow Angle Percentage for an Effort									
	Left					**Right**				
	Unadjusted	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**	**Unadjusted**	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**
AVE	**0.761**	**0.761**	**0.765**			**0.653**	**0.653**	**0.667**		
STDEV	**0.311**	**0.311**	**0.303**			**0.315**	**0.315**	**0.312**		
% Diff	**0.532**	**0.532**	**N/A**	**8.580**	**8.580**	**2.079**	**2.079**	**N/A**	**6.914**	**6.914**

	>135 Elbow Angle Percentage for an Effort									
	Left					**Right**				
	Unadjusted	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**	**Unadjusted**	**Adjusted**	**Full**	**Unadjusted Ave % diff**	**Adjusted Ave % diff**
AVE	**0.227**	**0.227**	**0.223**			**0.336**	**0.336**	**0.324**		
STDEV	**0.311**	**0.311**	**0.298**			**0.313**	**0.313**	**0.311**		
% Diff	**1.875**	**1.875**	**N/A**	**14.104**	**14.104**	**3.865**	**3.865**	**N/A**	**14.332**	**14.332**

Table 11: Flexion/Extension Statistical Summary

	Overall Flexion/Extension Percentage									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.164	0.164	0.164			0.164	0.164	0.164		
STDEV	0.341	0.341	0.328			0.350	0.350	0.345		
% Diff	0.000	0.000	N/A	12.380	12.380	0.000	0.000	N/A	10.611	10.611

	High Flexion Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.000	0.000	0.000			0.000	0.000	0.001		
STDEV	0.001	0.001	0.001			0.001	0.001	0.003		
% Diff	2.991	2.991	N/A	0.096	0.096	78.539	78.539	N/A	3.420	3.420

	Moderate Flexion Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.006	0.006	0.010			0.007	0.007	0.011		
STDEV	0.029	0.029	0.038			0.025	0.025	0.041		
% Diff	41.746	41.746	N/A	10.207	10.207	33.299	33.299	N/A	12.823	12.823

	Low Flexion Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.132	0.132	0.127			0.071	0.071	0.077		
STDEV	0.271	0.271	0.227			0.209	0.209	0.200		
% Diff	3.829	3.829	N/A	25.713	25.713	7.690	7.690	N/A	10.387	10.387

	Low Extension Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.825	0.825	0.828			0.894	0.894	0.892		
STDEV	0.302	0.302	0.243			0.235	0.235	0.213		
% Diff	0.410	0.410	N/A	17.193	17.193	0.179	0.179	N/A	4.886	4.886

Table 11 Continued

	Moderate Extension Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.036	0.036	0.034			0.026	0.026	0.018		
STDEV	0.126	0.126	0.099			0.101	0.101	0.054		
% Diff	8.467	8.467	N/A	19.874	19.874	44.681	44.681	N/A	20.685	20.685

	High Extension Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.000	0.000	0.000			0.002	0.002	0.002		
STDEV	0.000	0.000	0.000			0.006	0.006	0.004		
% Diff	0.000	0.000	N/A	0.000	0.000	15.656	15.656	N/A	10.439	10.439

Table 12: Grip Statistical Summary

	Overall Grip Percentage									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.143	0.143	0.143			0.143	0.143	0.143		
STDEV	0.303	0.303	0.288			0.287	0.287	0.278		
% Diff	0.000	0.000	N/A	9.895	9.895	0.000	0.000	N/A	13.275	13.275

	Power Hook Grip Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.100	0.100	0.099			0.117	0.117	0.117		
STDEV	0.268	0.268	0.258			0.270	0.270	0.271		
% Diff	1.074	1.074	N/A	2.876	2.876	0.039	0.039	N/A	7.448	7.448

	Oblique Grip Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.000	0.000	0.000			0.003	0.003	0.002		
STDEV	0.000	0.000	0.000			0.012	0.012	0.007		
% Diff	0.000	0.000	N/A	0.000	0.000	79.514	79.514	N/A	7.204	7.204

	Palmer Grip Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.118	0.118	0.107			0.113	0.113	0.099		
STDEV	0.299	0.299	0.261			0.251	0.251	0.214		
% Diff	10.006	10.006	N/A	7.163	7.163	13.749	13.749	N/A	7.957	7.957

	Palmer Pinch Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.114	0.114	0.128			0.078	0.078	0.076		
STDEV	0.268	0.268	0.238			0.209	0.209	0.187		
% Diff	10.834	10.834	N/A	17.587	17.587	2.859	2.859	N/A	13.999	13.999

Table 12 Continued

	2 or 3 Point Pinch Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.373	0.373	0.391			0.526	0.526	0.540		
STDEV	0.428	0.428	0.412			0.409	0.409	0.384		
% Diff	4.637	4.637	N/A	19.043	19.043	2.581	2.581	N/A	16.886	16.886

	Key Pinch Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.018	0.018	0.013			0.002	0.002	0.022		
STDEV	0.052	0.052	0.036			0.006	0.006	0.102		
% Diff	40.401	40.401	N/A	5.698	5.698	93.125	93.125	N/A	6.816	6.816

	Contact Grip Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.277	0.277	0.262			0.162	0.162	0.144		
STDEV	0.361	0.361	0.341			0.213	0.213	0.202		
% Diff	5.742	5.742	N/A	16.902	16.902	12.038	12.038	N/A	32.613	32.613

Table 13: Wrist Deviation Statistical Summary

	Overall Wrist Deviation Percentage									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.250	0.250	0.250			0.250	0.250	0.250		
STDEV	0.390	0.390	0.392			0.378	0.378	0.377		
% Diff	0.000	0.000	N/A	15.995	15.995	0.000	0.000	N/A	11.904	11.904

	High Ulnar Wrist Deviation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.047	0.047	0.045			0.022	0.022	0.018		
STDEV	0.188	0.188	0.184			0.104	0.104	0.086		
% Diff	4.440	4.440	N/A	8.303	8.303	25.211	25.211	N/A	9.862	9.862

	Moderate Ulnar Wrist Deviation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.126	0.126	0.126			0.055	0.055	0.070		
STDEV	0.278	0.278	0.275			0.120	0.120	0.151		
% Diff	0.068	0.068	N/A	16.870	16.870	21.674	21.674	N/A	11.088	11.088

	Neutral Wrist Deviation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.742	0.742	0.759			0.771	0.771	0.778		
STDEV	0.358	0.358	0.346			0.313	0.313	0.303		
% Diff	2.166	2.166	N/A	15.809	15.809	0.920	0.920	N/A	18.948	18.948

	Radial Wrist Deviation Percentage for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.085	0.085	0.070			0.152	0.152	0.134		
STDEV	0.215	0.215	0.201			0.283	0.283	0.261		
% Diff	20.765	20.765	N/A	22.997	22.997	13.403	13.403	N/A	7.717	7.717

Table 14: RPE Statistical Summary

	Average RPE for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.835	0.831	0.822			0.901	0.899	0.896		
STDEV	0.467	0.469	0.456			0.462	0.461	0.443		
% Diff	1.571	1.069	N/A	5.281	4.484	0.622	0.392	N/A	3.398	3.698

	Average RPE for a Job									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.609	0.609	0.642			0.685	0.685	0.728		
STDEV	0.416	0.415	0.422			0.414	0.414	0.431		
% Diff	5.137	5.103	N/A	11.709	11.752	5.917	5.899	N/A	10.361	10.333

	Maximum RPE									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	1.210	1.210	1.242			1.323	1.323	1.387		
STDEV	0.990	0.990	0.999			0.791	0.791	0.844		
% Diff	2.597	2.597	N/A	1.613	1.613	4.651	4.651	N/A	2.688	2.688

Table 15: Average Effort for a Job Statistical Summary

	Average Effort for a Job									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	0.822	0.822	0.813			0.889	0.889	0.888		
STDEV	0.441	0.441	0.425			0.462	0.462	0.437		
% Diff	1.131	1.131	N/A	3.746	3.746	0.120	0.120	N/A	4.711	4.711

Table 16: Hand Wrist Posture Statistical Summary

	Average Hand Wrist Posture									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	1.501	1.501	1.528			1.422	1.422	1.441		
STDEV	0.673	0.673	0.690			0.570	0.570	0.598		
% Diff	1.776	1.776	N/A	10.315	10.315	1.318	1.318	N/A	5.332	5.332

	Maximum Hand Wrist Posture									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	2.323	2.323	2.645			2.452	2.452	2.645		
STDEV	1.376	1.376	1.496			1.434	1.434	1.518		
% Diff	12.195	12.195	N/A	7.742	7.742	7.317	7.317	N/A	4.301	4.301

Table 17: Speed Statistical Summary

	Average Speed for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	2.474	2.474	2.504			2.716	2.716	2.708		
STDEV	0.768	0.768	0.733			0.638	0.638	0.638		
% Diff	1.186	1.186	N/A	2.017	2.017	0.285	0.285	N/A	0.339	0.339

	Average Speed for a Job									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	2.091	2.091	2.231			2.401	2.401	2.516		
STDEV	0.686	0.686	0.727			0.596	0.596	0.659		
% Diff	6.262	6.250	N/A	7.132	7.119	4.576	4.565	N/A	6.460	6.447

	Maximum Speed									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff
AVE	2.613	2.613	2.613			2.774	2.774	2.774		
STDEV	0.667	0.667	0.667			0.617	0.617	0.617		
% Diff	0.000	0.000	N/A	0.000	0.000	0.000	0.000	N/A	0.000	0.000

Table 18: Average Posture for an Effort Statistical Summary

	Average Posture for an Effort									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diffj	Adjusted Ave % diff
AVE	1.452	1.548	1.546			0.500	0.500	0.500		
STDEV	0.727	0.767	0.778			0.688	0.688	0.688		
% Diff	6.068	0.102	N/A	13.031	7.072	0.579	0.579	0.561	4.711	4.711

Table 19: Efforts per Minute Statistical Summary

	Efforts Per Minute									
	Left					Right				
	Unadjusted	Adjusted	Full	Unadjusted Ave % diff	Adjusted Ave % diff	Unadjusted	Adjusted	Full	Unadjusted Ave % diffj	Adjusted Ave % diff
AVE	40.737	29.167	26.312			51.937	49.849	43.044		
STDEV	16.957	19.650	18.935			26.257	27.094	25.225		
% Diff	54.823	10.852	N/A	146.443	21.959	20.659	15.809	N/A	31.221	23.692

APPENDIX D

ICC RESULTS OF UNADJUSTED VERSUS FULL DATA AND ADJUSTED VERSUS FULL DATA

Table 20: Forearm Rotation ICC Results

Forearm Rotation Percentage for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.987	0.987		0.975	0.975

Table 21: Elbow Angle ICC Results

Elbow Angle Percentage for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.996	0.996		0.994	0.994

Table 22: Flexion/Extension ICC Results

Flexion/Extension Percentage for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.95	0.95		0.992	0.992

Table 23: Grip ICC Results

Grip Percentage for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.967	0.967		0.95	0.95

Table 24: Wrist Deviation ICC Results

Wrist Deviation Percentage for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.977	0.977		0.98	0.98

Table 25: RPE ICC Results

Average RPE for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.969	0.986		0.991	0.991

Average RPE for a Job				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.977	0.977		0.967	0.967

Maximum RPE				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.984	0.984		0.953	0.953

Table 26: Average Effort for a Job ICC Results

Average Effort for a Job				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.988	0.988		0.985	0.985

Table 27: Hand Wrist Posture ICC Results

Average Hand Wrist Posture				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.894	0.894		0.952	0.952

Maximum Hand Wrist Posture				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.832	0.832		0.871	0.871

Table 28: Speed ICC Results

Average Speed for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.992	0.992		0.999	0.999

Average Speed for a Job				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.977	0.977		0.940	0.940

Maximum Speed				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
1.000	1.000		1.000	1.000

Table 29: Average Posture for an Effort ICC Results

Average Posture for an Effort				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.652	0.945		1.000	0.953

Table 30: Efforts per Minute ICC Results

Efforts Per Minute				
Left			Right	
Unadjusted	Adjusted		Unadjusted	Adjusted
0.621	0.966		0.93	0.947

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